**Developing an Ecological Integrity Index for Shrublands:
Measures to Promote Migratory Bird and New England Cottontail Habitat**

Final Report to the United States Fish and Wildlife Service

2009

Lesley Sneddon, Senior Regional Ecologist, NatureServe
11 Avenue de Lafayette
Boston, MA 02111

November 10, 2009

On the cover: Tall maritime shrubland, Parker River NWR
photo by Nancy Pau

Table of Contents

Table of Figures

Introduction

In previous work, NatureServe and J.W. Sewall and Co. worked in collaboration to produce vegetation maps of Parker River, Ninigret, Rachel Carson, and Great Meadows National Wildlife Refuges as part of a larger mapping effort that included many New England refuges. The common map unit for all refuges was the association level of the National Vegetation Classification (NatureServe 2009). In the current project, ecologists of NatureServe were requested to enter into a cooperative agreement with the USFWS to apply the information in the vegetation maps and to build upon an extensive database of regional vegetation and experience in the development of an ecological integrity index that can be applied in long-term monitoring of managed shrublands.

Biologists of USFWS National Wildlife Refuges of coastal and near-coastal New England have proposed goals and objectives pertaining to management of shrublands (O'Brien et al. 2008):

Goal 1:   To provide native shrub habitat for fall migrating birds
Objectives: a) determine minimum patch size of habitat
              b) determine vegetation structure and species composition of habitat

Goal 2:   To preserve biological diversity and ecological integrity
Objectives: a) minimize presence of non-native invasive plants

Goal 3:[1]   To provide native shrub habitat for a sustainable population of New England
              cottontail rabbits.
Objectives: a) determine appropriate patch size and configuration
              b) determine appropriate vegetation structure and composition

The four refuges (Parker River and Great Meadows, Massachusetts), Rachel Carson (Maine), and Ninigret (Rhode Island) differ in environmental setting and so require different approaches to meeting these goals. Parker River and Ninigret refuges are the most similar to each other in occupying southern New England maritime dune settings which are affected by strong offshore winds, salt spray, and storms. Rachel Carson also occupies a maritime setting but the study area occurs in a more sheltered location on loamy soil as opposed to sand. Great Meadows differs in its more inland rather than maritime setting, and as such is not affected by coastal processes.

Ecological Integrity Index

Background

Ecological integrity refers to the degree to which an ecosystem resembles the natural or historical range of variation of that ecosystem in function, species composition, and vegetation structure. Ecological integrity is a complex concept that embodies a great number of variables, presenting some real challenges in monitoring and management. In recent years, NatureServe, in collaboration

---

[1] Goal 3 is being actively pursued at the two refuges where New England cottontail rabbits have been documented: Rachel Carson and Ninigret

with a number of partners, has developed an approach to assessing ecological integrity by identifying key variables and a set of standard, repeatable measures of those variables (Faber-Langendoen et al. 2009). This process allows for the establishment of a baseline assessment, and a means to detect change over time. In general, the method first identifies the major ecological attributes to be measured: landscape context and condition, patch size, vegetation, substrate, and stressors. Each attribute is assessed separately and assigned a value based on the metrics provided, and the metrics are integrated into an overall rank, or index. To calculate the index, we used a metrics Excel workbook developed by NatureServe (Faber-Langendoen et al. 2008). The metrics spreadsheet provides a range of values for each metric, and the user enters the appropriate scores for each. Land use and stressor impacts both require the evaluation of a number of factors, so a land use index and a stressor impact evaluation are calculated in separate spreadsheets and those scores are pulled into the overall metrics spreadsheet.

The management goals of refuge staff are to establish a baseline assessment of an identified patch of shrubland within the refuge, against which to compare the effectiveness of differing management strategies. Landscape connectivity and surrounding land use are neither within the purview of the USFWS staff, nor likely to change significantly over the period of adaptive management. The patch size to be assessed was also selected a priori and as a fixed measure would not change. For this reason, we deviated from the above methods and did not evaluate patch size or landscape context in calculation of the baseline index.

The metrics we measured in this project are described below.

Vegetation Metrics
Four vegetation metrics were developed: a) vegetation structure, b) invasive exotic plants, c) vegetation composition, and d) relative percent cover of native species.
- Vegetation structure is defined as an assessment of the proportion of structural stage or age-class distribution, based on canopy and stem-size characteristics of the vegetation layers.
- Invasive exotic plants metric is defined as the percent cover of a selected set of exotic species that are considered invasive. Non-native species that are not considered to be invasive are not included in this metric. Scores range from sustainable (no invasive species present) to very degraded (mapped invasive species overlap >25% of the patch boundaries).
- Vegetation composition is defined as an assessment of the overall species composition and diversity, of the dominant vegetation layer, and evidence of specific species diseases or mortality. Scores range from sustainable (vegetation is close to reference conditions; allows for minor evidence of past but recovering disturbance) to degraded (vegetation composition severely altered from desired conditions)
- Relative percent cover of native species is defined as the relative percent cover of the plant species that are native to the region with respect to total vegetation cover. Scores range from sustainable (>95% cover of native species) to degraded (<50% cover of native species)

Soil / Substrate Metrics
Two metrics were developed for measurement of soil or substrate effects: a) soil / substrate condition and b) on-site land use
- Soil / substrate condition is defined as an assessment of physical disturbances to the soil and surface substrates of the area. Examples include filling, grading, plowing, and other

mechanical disturbances. Scores range from sustainable (no apparent soil modifications) to degraded (recent and severe soil disturbances)

- On-site land use is defined as an index of the intensity of human dominated land uses within the occurrence. In effect, some land uses have more negative impacts than do others. In this metric, GIS is used to measure the types of surrounding land use. This metric is derived from the calculation of land use coefficient (Table 1).

Table 1. Land Use Coefficient Table (modified from Hauer et al. 2002)

Current Land Use	Coefficient
Paved roads/parking lots/domestic or commercially developed buildings/mining (gravel pit, quarry, open pit, strip mining).	0
Unpaved Roads (e.g., driveway, tractor trail) / abandoned mines	0.1
Agriculture (tilled crop production) / intensively developed vegetation (golf courses, lawns, etc).	0.2
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	0.3
Heavy logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Intense recreation (ATV use/camping/sport fields/popular fishing spot, etc.) / Military training areas (armor, mechanized)	0.4
Heavy grazing on rangeland or pastures	0.4
Agriculture - permanent crop (vineyards, orchards, nurseries, berry production, introduced hay field and pastures etc)	0.4
Commercial tree plantations / christmas tree farms	0.5
Dam sites and flood disturbed shorelines around water storage reservoirs	0.5
Recent old fields and other disturbed fallow lands dominated by ruderal and exotic species.	0.5
Moderate grazing on rangeland	0.6
Moderate recreation (high-use trail)	0.7
Mature old fields and other fallow lands with natural composition	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail) / haying of native grassland.	0.9
Natural area / land managed for native vegetation	1

Hydrology Metrics

Two hydrologic metrics, floodplain interactions and non-riparian alterations, were applicable to the current study.

- Floodplain interactions is an assessment of the degree to which flooding and geomorphic structure of floodplains have been impacted by negative anthropogenic alterations.

- Non-riparian is an assessment of the general factors impacting hydrology in non-riverine systems, such as ditching, water diversions and the like.

Although the final ecological integrity index is four simple levels – A: Sustainable+; B: Sustainable; C: transitioning; and D: degraded – it is derived from computation of many different variables, as described in the metrics above. Each component is measured, and monitored, separately, so that there are multiple routes to reaching a threshold and thus transitioning to a different level.

Methods

Vegetation structure criteria were written to specifically target shrublands. Baseline indices are based in part on remote measurement using available aerial photography. Photos for Parker River are from 2008 USGS Color Ortho Imagery flown in April, with pixel resolution of 30 cm (MassGIS) Great Meadows photography is Color Ortho Imagery flown in spring 2005 (MassGIS); Rachel Carson photography is true color flown between 2003 and 2005 (MEGIS), and Ninigret photography is true color 2-foot pixel resolution flown in spring 2003 to 2004 (RIGIS).

Canopy closure was determined by drawing nine arbitrarily placed 20x20-m polygons on the image and estimating canopy closure, then determining the mean. Stereo pairs were not available so no attempt was made to estimate vertical structural diversity from photography.

Invasive exotic plant cover was either estimated from a field visit, or referred directly to pre-existing maps of invasive species provided by the refuge biologists. Vegetation composition was ranked by comparing present conditions to desired condition, as described in detail below. Relative cover of native plant species was also estimated for each of the study areas. This measure is particularly applicable in old fields, where invasive exotic species may be present at low cover. This measure alone does not account for the fact that the overall composition of old fields is dominated by non-native species, many of which are not considered invasive.

Soil condition was evaluated based on current or inferred past land use: old fields and the former runways at Ninigret were considered to be transitioning, and were assumed to have been plowed or otherwise altered.

Hydrology was evaluated at Great Meadows where two of the three sites are wetlands, and to a lesser extent at Rachel Carson where there are small wetland areas within the study area. Hydrologic impacts were surmised from examining aerial photography.

Parker River National Wildlife Refuge: Existing Vegetation

At 450 acres, Parker River has one of the largest, if not the largest, Successional Maritime Forest occurrences in the northeast. This assessment was made by measuring the acreage of other known sites supporting this association using GIS on aerial photography. Successional Maritime Forest generally occurs on sheltered back dunes, in a largely continuous patch spanning the length of the refuge. As one approaches the shore it is broken up and forms a mosaic with Northern Beach Heather Dune Shrubland and Northern Bayberry Dune Shrubland.

Successional Maritime Forest is generally characterized by densely distributed tall shrubs and wind-pruned trees such as *Prunus serotina* (black cherry)*, Juniperus virginiana* (eastern red-cedar)*, Amelanchier canadensis* (shadbush)*, Celtis occidentalis* (hackberry), and *Viburnum dentatum.* Vines are common, including *Parthenocissus quinquefolia* (Virginia creeper) and *Toxicodendron radicans* (poison ivy)*. Quercus velutina* (black oak), *Quercus alba* (white oak) and *Pinus rigida* (pitch pine) also occur, particularly in more protected locations. Invasive exotic species, including *Frangula alnus*) are present and in some areas very prevalent. McDonnell's (1979) flora of Plum Island described this vegetation as "a mixture of scrub forest and shrub thicket" of the backdune, dominated by *Prunus serotina, Amelanchier canadensis,* and *Acer rubrum* (red maple). Other associates included *Quercus velutina*, *Celtis occidentalis, Sassafras albidum* (sassafras), and *Nyssa sylvatica* (black gum). He described the understory as variable, but most often characterized by *Aralia nudicaulis* (wild sarsparilla), *Toxicodendron radicans*, *Arenaria lateriflora (=Moehringia lateriflora)* (bluntleaf sandwort), *Teucrium canadense* (Canada germander), and *Smilax rotundifolia* (common greenbrier). He noted that the largest and oldest example of this vegetation was located behind High Sandy in the Kettle Hole.

The management goals of Parker River NWR are to maintain or increase habitat for migratory birds and to decrease the percent cover of invasive exotic plants. Restoration of both the grassland and shrubland units will not add significant acreage of migratory bird habitat, but removal of invasive species and restoration to native vegetation will improve ecological integrity. Refuge biologist Nancy Pau selected two areas for maritime shrubland adaptive management (Figure 1). One area is in the central part of the refuge in an old field adjacent to a large impounded wetland, and the other is a section of tall shrubland less than 1 km to the north.

Figure 1 Areas selected for shrubland adaptive management at Parker River NWR.

The grassland unit, seven acres of a 33-acre old field, is characterized by scattered low shrubs and saplings intermixed with grasses and forbs. It is classified as Northeastern Old Field (*Dactylis glomerata - Phleum pratense - Festuca* spp. - *Solidago* spp. Herbaceous Vegetation)

with the NVC code CEGL006107. A 10m x 10m plot representing this vegetation was taken in August 2008. *Morella (=Myrica) pensylvanica* (bayberry) was the most abundant shrub, providing approximately 25% cover. Other woody species included *Prunus serotina, Prunus maritima* (beach plum), *Amelanchier canadensis, Rosa virginiana* (Virginia rose), *Frangula alnus,* and *Juniperus virginia* provided 5% or less cover. The field layer was 95% cover and characterized by forbs and grasses, the most abundant of which included *Phleum pratense* (timothy), *Deschampsia flexuosa* (wavy hairgrass), *Festuca* spp. (fescue species), *Achillea millefolium* (Queen Anne's Lace), and *Euphorbia cyparissias)* (cypress spurge).

The shrubland unit is 17 acres comprised of several associations. The tall shrubland occupies two patches totaling 9.5 acres classified as Successional Maritime Forest , or *Prunus serotina - Sassafras albidum - Amelanchier canadensis - Quercus velutina / Smilax rotundifolia* Forest (NVC code CEGL006145). This stand is dominated by *Prunus serotina* and *Amelanchier canadensis,* with an understory characterized by *Morella pensylvanica.* Invasive exotic woody species are also present in quantity at this stand, including *Robinia pseudoacacia* (black locust), *Lonicera morrowii* (Morrow's honeysuckle) and *Frangula alnus.* The two patches of Successional Maritime Forest are separated by Northern Bayberry Dune Shrubland, or *Morella (= Myrica) pensylvanica - Prunus maritima* Shrubland (NVC code CEGL006295) and Northern Beach Heather Dune Shrubland, or *Hudsonia tomentosa - Arctostaphylos uva-ursi* Dwarf-shrubland (NVC code 6143). Several small interdunal wetlands occur within this management unit as well.

Ninigret National Wildlife Refuge: Existing Vegetation

The management goals of Ninigret National Wildlife Refuge are the same as those of Parker River, with the addition of the goal to maintain or increase, and improve the quality of habitat for New England cottontail rabbits. Ninigret is located on a former naval air field, and remnants of runways are still evident. Refuge biologist Suzanne Payton selected approximately 32 acres of a 375-acre site occupying the south-central portion of the former air field (Figure 2) for management.

**Figure 2 Area selected for shrubland management at Ninigret NWR**

The current vegetation of a portion of the management area is a forest of 3m in height dominated by *Prunus serotina* and *Amelanchier canadensis; Acer rubrum* is a common associate. The shrub layer is characterized by *Vaccinium corymbosum* and *Clethra alnifolia* (sweet pepperbush) in more mesic areas. A short shrub layer is characterized by *Vaccinium corymbosum* (highbush blueberry)*, Viburnum dentatum,* and *Gaylussacia baccata* (black huckleberry)*. Ilex verticillata* (winterberry) occurs but is uncommon, and *Morella pensylvanica* is common throughout. The understory is relatively open, and characterized by a dense growth of *Carex pensylvanica* (Pennsylvania sedge)*,* with associates including *Solidago rugosa* (rough goldenrod)*, Rubus* spp., (blackberries, dewberries and raspberries) and *Solidago latissimifolia* (Elliott's goldenrod). Vines include *Toxicodendron radicans* and *Lonicera morrowii.* The invasive species *Celastrus orbiculatus* (oriental bittersweet) is abundant, and has achieved a robust state, with stems several inches in diameter and reaching high into the tree canopy, itself contributing significant canopy cover. In other areas of the management area, *Vitis labrusca* (fox grape) is common and produces abundant fruit.

Great Meadows National Wildlife Refuge

Great Meadows is largely wetland habitat bordering the Concord and Sudbury Rivers, and the property also includes some upland forests and old fields. While old field habitat is not a management priority at Great Meadows, the existing old fields are characterized by an abundance of invasive exotic species, and the fields are mowed or hydroaxed periodically to reduce the abundance of exotics. Biologist Stephanie Koch is considerting conversion of one or more of fields to native shrublands to increase habitat for neotropical migratory birds and to decrease the cover of invasive species.

Three old field sites were examined for potential conversion to shrublands (Figure 3). The northernmost site, Hunter field, is seasonally flooded, as evidenced by the presence of wetland plants and a soil profile characterized by a 12" organic horizon over orange-mottled sands. The water table was noted to be at 18" during the field visit in August 2008. The vegetation is largely herbaceous with scattered shrubs, including *Alnus incana* (gray alder), *Salix* sp. (willow), and *Rhamnus cathartica* (European buckthorn). The herbaceous layer was diverse, and included *Scirpus atrovirens* (green bulrush), *Juncus effusus* (soft rush), *Onoclea sensibilis* (sensitive fern), *Euthamia graminifolia* (grass-leaved goldenrod), *Asclepias syriaca* (common milkweed), *Thelypteris palustris* (marsh fern), *Carex scoparia* (broomsedge), and many others.
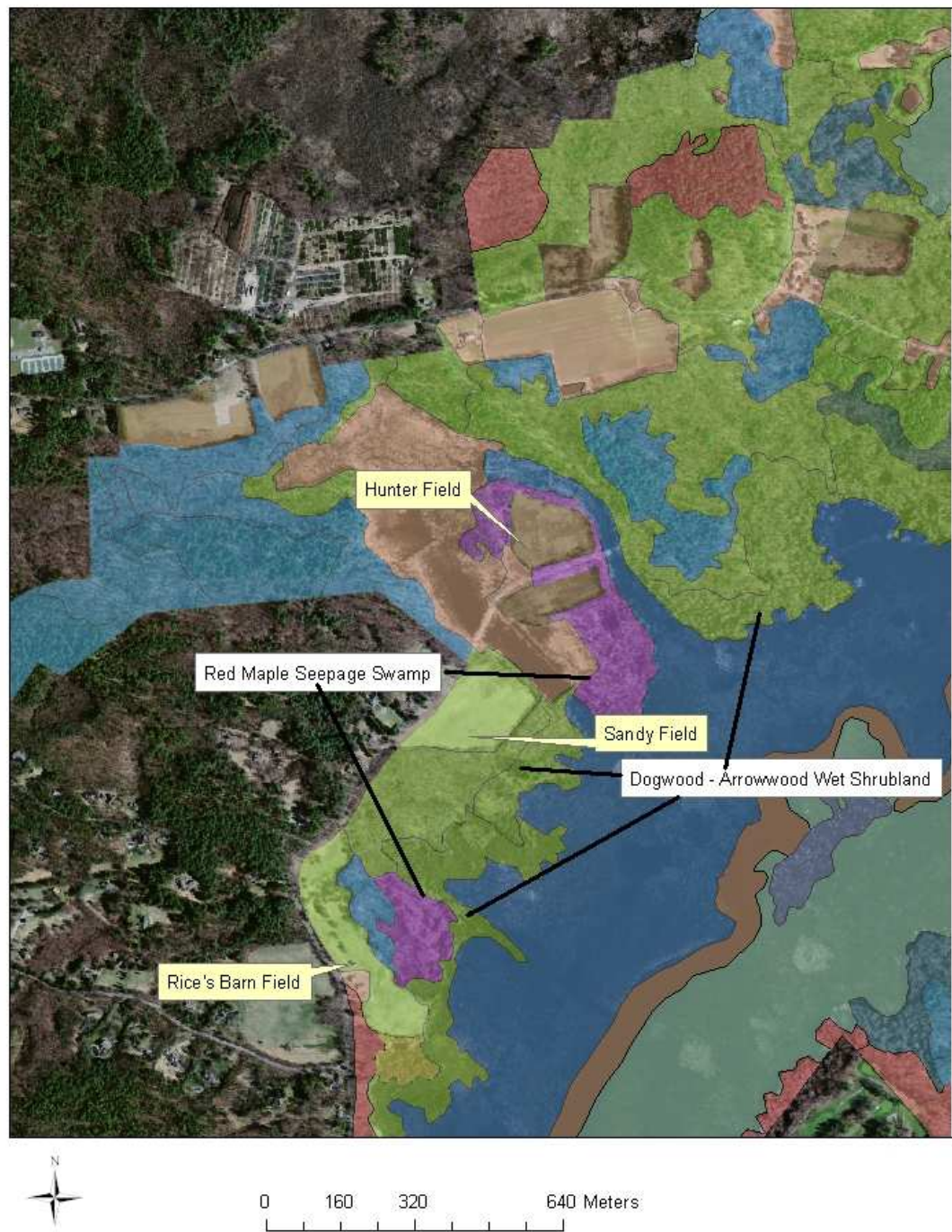
Figure 3 Great Meadows NWR study sites

The second proposed site, referred to here as "sandy field", is an old field that supports a smaller area of sandy soils lacking profile development. The vegetation here is dominated by *Schizachyrium scoparium* (little bluestem) and *Eragrostis spectabilis* (purple love-grass) with other old-field species such as *Asclepias syriaca*, *Ambrosia artemisiifolia* (annual ragweed), and scattered seedlings of *Prunus serotina*.

The third site, Rice's Barn Field, is a sloping old field that is characterized by a number of invasive species, including *Centaurea maculosa* (spotted knapweed), *Rhamnus cathartica, Celastrus orbiculatus* and *Lonicera* spp. (honeysuckle), as well as *Solidago rugosa*, and *Festuca* spp. (fescue). There are scattered low shrubs including *Vaccinium angustifolium* (lowbush blueberry) and *Gaylussacia baccata*. Along the lower slope adjacent to the river, wetland plants occur over a deep organic layer. *Calamagrostis canadensis* (bluejoint) is the dominant grass, and *Impatiens capensis* (jewelweed) is common. Wetland shrubs are common, including *Cornus amomum* (silky dogwood) and *Ilex verticillata*, as well as abundant *Viburnum dentatum*.

Rachel Carson NWR

The primary management objective for Rachel Carson NWR is to improve and maintain shrubland habitat to support New England cottontail rabbits. Secondary goals are to provide migratory bird habitat and to decrease the cover of invasive species. Three fields on the Cutts Island area of the Brave Boat Harbor division known to support New England cottontails (Figure 4) were selected for management by biologist Kate O'Brien. New England cottontail requires dense shrubland habitat with a high stem density, as well as a general absence of trees serving as raptor perches. The three fields are essentially contiguous and cover approximately 18 acres in aggregate. Additional habitat can be added by opening the canopy of adjacent forests to stimulate more vigorous shrubland growth.

Cutts 1 lies adjacent to a salt marsh with restricted tidal flooding, and during storm surges, parts may be inundated with salt water. It is currently characterized by non-native pasture grasses including *Poa pratensis* (Kentucky bluegrass) and *Festuca rubra* (red fescue)*,* and forbs such as *Potentilla canadensis* (dwarf cinquefoil)*, Rumex acetosella* (common sheep sorrel)*, Solidago rugosa, Plantago lanceolata* (narrow leaf plantain)*,* and others. The invasive shrub *Frangula alnus* is common. Native shrubs occurring here include *Viburnum dentatum, Spiraea alba* (white meadowsweet), *Rhus typhina (*staghorn sumac), *Amelanchier* spp., *Ilex verticillata*, *Rubus flagellaris* (northern dewberry) and *Rubus allegheniensis* (Allegheny blackberry).

Cutts 2 is characterized by a greater shrub cover than is Cutts 1. Scattered *Quercus* spp. (oaks) and *Carya* spp. (hickories) are present. *Frangula alnus* is abundant in this field, and other non-native shrub associates include *Rosa multiflora* (multiflora rose)*, Celastrus orbiculata, Lonicera* spp. (honeysuckles), and *Berberis thunbergii* (Japanese barberry)*.* Native shrubs include *Rubus flagellaris* (northern dewberry) and *Rubus allegheniensis* (Allegheny blackberry), *Spiraea alba*), *Ilex verticillata, Prunus pensylvanica* (choke cherry)*,* and *Viburnum dentatum.*

Cutts 3 includes some wetland areas, and has a diverse vegetation structure, including stands of *Quercus* spp., *Carya* spp., and *Prunus serotina*; shrubby areas dominated by *Frangula alnus,* and pasture grasses and forbs.

An unpublished paper by the refuge biologists (O'Brien et al. 2008) proposed different treatments for each field. Cutts 1 was targeted for removal of invasives and shrub plantings in May 2009. Cutting and pulling of invasives was planned for Cutts 2 in September 2009, with possible planting. Prescribed burning was planned for Cutts 3 in September 2008, following removal of trees and buckthorn, and continued invasives removal in summer 2009.
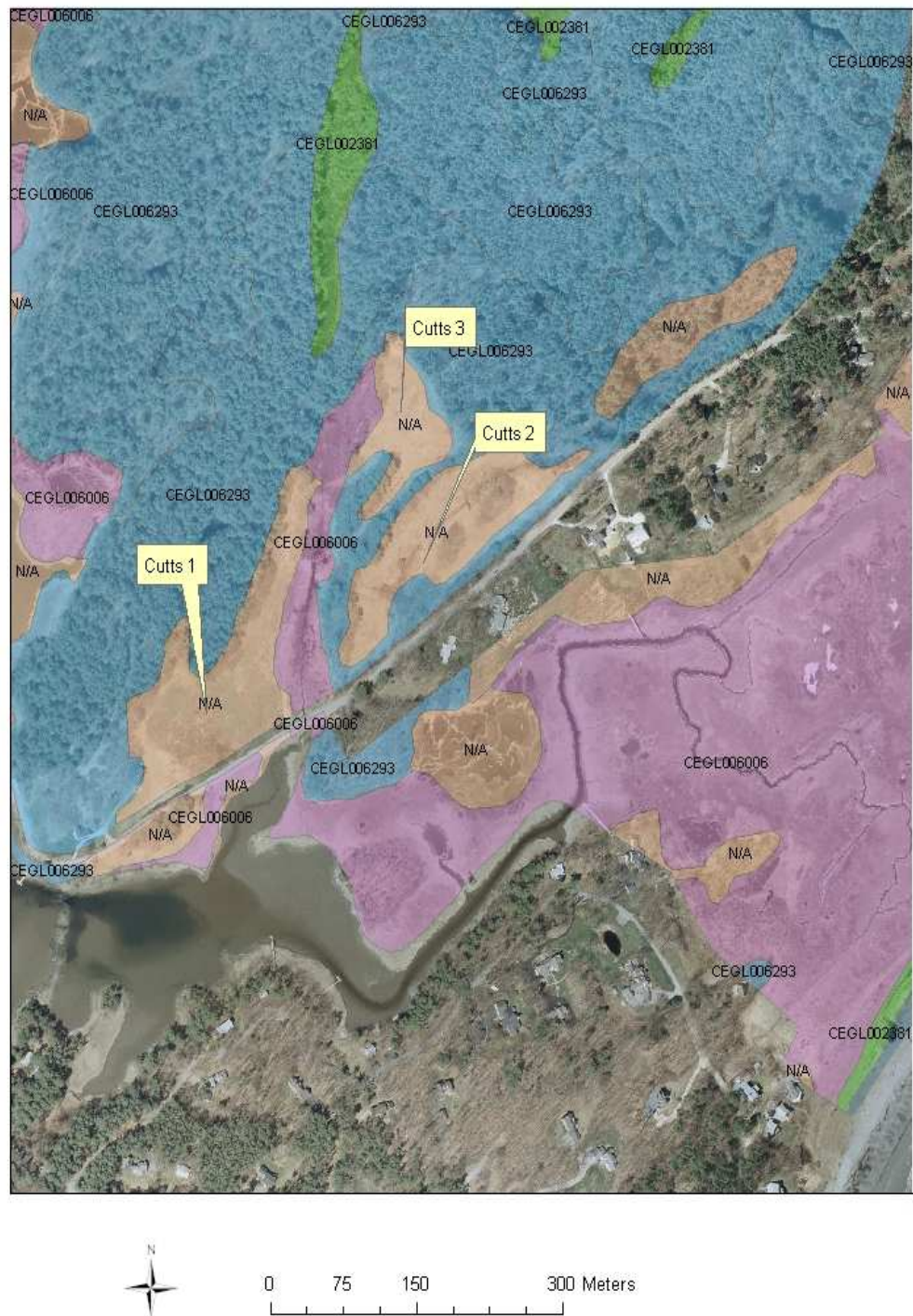
Figure 4 Rachel Carson NWR Study Sites

Results – Baseline Indices

<u>Parker River</u>

Tables 1 and 2 provide assessments of the grassland and shrubland units, respectively. The grassland unit bears little resemblance to the target vegetation, so the overall ranking is "C", or transitioning, with a numerical index of 2.5 out of a possible 5.0

The shrubland unit resembles the target vegetation in structure and composition, but requires removal of exotic species, particularly *Rhamnus cathartica and Lonicera morrowii*. The overall rank for the shrubland unit is "B", or sustainable, with a numerical index of 3.6.

<u>Ninigret</u>

Although Ninigret has a history of intensive land use as a former air field, the refuge is recovering following the removal of asphalt from the old runways, and is relatively isolated from the impacts of human development. The overall rank is "C", or transitioning. The numerical index is 2.5 (Table 3).

Table 1 Ecological Integrity Index for Parker River National Wildlife Refuge Grassland Unit

Major Attribute	Metric	Point Scale	Field Value	Field Score	Metric Weight	Weighted Field Score
VEGETATION						
V1. Vegetation Structure[2]	An assessment of the overall structural complexity of the dominant vegetation layer, including the density, stem size, and canopy cover relative to target conditions. Specific variants are provided for Forest, Woodland, Shrubland/Dwarf-shrubland - closed, Shrubland/Dwarf-shrubland-open, Herbaceous-Grassland&Meadow, Herbaceous-Shrub Steppe, and Herbaceous-Tree Savanna.			1	1	1
Target condition	Viewed remotely, average shrub cover over the stand area is high (≥90%). There is high diversity in vertical structure (i.e. tall shrub layer 25%, emergent trees 5%) resulting in high fruit production. Field layer (<1m) is >90% closed, with most cover contributed by shrubs	5				
Near target condition	Average shrub cover over the stand area is relatively high (>70-90%). Diversity of vertical structure may be somewhat variable, but overall fruit production is high. Field layer is >70% closed. Herbaceous cover of field layer may contribute up to 25% cover	4				
Sub-target condition	Remotely viewed shrub cover is partially open (50-70%). Herbaceous cover of patches not occupied by shrubs is generally greater than 75% and exceeding 0.5m in height.	3				
Highly altered	Remotely viewed shrub cover is open (25-50%). Herbaceous cover of patches not occupied by shrubs is generally greater than 50%, only partially exceeding 0.5m in height on average	2				
Degraded	Remotely viewed shrub cover is low (<25%). Herbaceous cover of open patches less than 25% cover and / or less than 0.5 m in height; areas of bare ground may be significant	1				
V2. Invasive Exotic Plants[3]	The percent cover of a selected set of exotic species that are considered invasive.			3	1	3
Target condition	No key invasive species present OR County level data shows no key invasives present.	5				
Near target condition	Key invasive species 1-2% cover OR County level data shows presence of 1 key invasive exotic species.	4				
Sub-target condition	Key invasive species 3- 5% OR GIS layers show actual mapped key invasive exotic species overlap site boundaries, OR County level data shows presence of 2-3 key invasive exotic species.	3				
Highly altered	Key invasive species 5-25% OR GIS layers show actual mapped key invasive exotic patches that overlap >10% of the site boundaries, OR County level data shows presence of 4-5 key invasive exotic species.	2				
Degraded	Key invasive species >25% OR GIS layers show actual mapped key invasive exotic species patches that overlap >25% of the site boundaries., OR County level data shows presence of more than 5 species of key invasive exotic species.	1				

---

[2] Shrub cover measured 8.3% on 2008 aerial photography
[3] *Frangula alnus* contributed 3-5% cover in a 10 x 10m plot

V3. Vegetation Composition[4]	An assessment of the overall species composition and diversity, of the dominant vegetation layer, and evidence of specific species diseases or mortality.			2	1	2
Target condition	Vegetation is at target condition in species present and their proportions. Dominant vegetation layer is composed of all native species, and all indicator/diagnostic species are present.	5			
Near target condition	Vegetation is at or close to target condition in species present and their proportions. Dominant vegetation layer may be composed of some native species reflective of past disturbance (e.g., pioneer or early successional species) and exotic plants are low in abundance. Some indicator/diagnostic species may be absent.	4			
Sub-target condition	Vegetation is different from target condition in species diversity or proportions, but still largely composed of native species characteristic of the type. This may include weedy (pioneer, early successional) native species that develop after clearcutting or clearing. Exotics may be common, but not dominant. Invasive species may be present in low numbers. Many indicator/diagnostic species may be absent.	3			
Highly altered	Vegetation altered from target in composition. Expected strata are unnaturally absent, or composed of exotic species, or composed of planted stands of non-characteristic species, or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent; invasive species are present in quantity and require great effort to remove.	2			
Degraded	Vegetation severely altered from target in composition. Expected strata are unnaturally absent or dominated by exotic species or composed of planted stands of non-characteristic species or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent, and / or invasive species are intractable by reasonably cost-effective means.	1			
V4. Relative Percent Cover of Native Plant Species (opt.)	The relative percent cover of the plant species that are native to the region with respect to total vegetation cover.		1	1	2
Target condition	>98% relative cover of native plant species	5			
Near target condition	85-97% relative cover of native plant species	4			
Sub-target condition	60-84% relative cover of native plant species	3			
Highly altered	45-59% relative cover of native plant species	2			
Degraded	<45% relative cover of native plant species	1			

[4] Considered highly altered as opposed to degraded due to presence of native shrub species at 25% cover in 10 x 10m plot; *Frangula alnus* present but could be removed with effort. Although herbaceous cover is comprised primarily of non-native grasses, these species are not considered invasive and will likely diminish with shade cast by increased shrub cover.

V5. Vegetation Stressors Checklist[5]	Use VEGETATION (BIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)		3 (3)	3	1	3
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

SOIL / SUBSTRATE						
S1. Soil/Substrate Condition	This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.			4?	1	3
Target condition	No Apparent Soil Surface Modifications	5				
Sub-target condition	Past Soil Surface Modification but Recovered; OR Recent but Minor Modifications	4				
Highly altered	Recovering OR Recent and Moderate Soil Surface Modifications	3				
Degraded	Recent and Severe Soil Surface Modifications	1				

S2. On-Site Land Use[6]	Use 'Land Use Index Worksheet' tab.		0.5	3	1	3
Target condition	Land Use Index = 1.0-0.95	5				
Sub-target condition	Land Use Index = 0.80-0.95	4				
Highly altered	Land Use Index = 0.4-0.80	3				
Degraded	Land Use Index = < 0.4	1				

S3. Soils/Substrate Stressors Checklist[7]	Use SOIL / SUBSTRATE (ABIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)		2 (1)	3	1	3
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

---

[5] Stressors included mowing, shrub removal, lack of effective treatment of invasive species; all influence >10% of the area

[6] Study area is entirely an old field, with land use index = 0.5

[7] Soil stressors include soil disturbances due to mowing > 10% of area; extensive filling presumed to have been done in this impoundment

Table 1 Ecological Integrity Index for Parker River National Wildlife Refuge Grassland Unit (concluded)

SUMMARY		Attribute			Overall
MAJOR ATTRIBUTE		**Score**	**Rating**	**Weight**	**Score**
Landscape Context		-	#N/A	1	
Size		-	#N/A	1	
Vegetation		2.2	C	1	
Soils/Substrate		3	C	1	
Hydrology		-	#N/A	0	
OVERALL SCORE					2.5
OVERALL RATING (Index of Ecological Integrity)					C
OVERALL RATING DESCRIPTION					Transitioning

Table 2 Ecological Integrity Index for Parker River National Wildlife Refuge Shrubland Unit

Major Attribute	Metric	Point Scale	Field Value	Field Score	Metric Weight	Weighted Field Score
VEGETATION						
V1. Vegetation Structure[8]	An assessment of the overall structural complexity of the dominant vegetation layer, including the density, stem size, and canopy cover relative to target conditions. Specific variants are provided for Forest, Woodland, Shrubland/Dwarf-shrubland - closed, Shrubland/Dwarf-shrubland-open, Herbaceous-Grassland&Meadow, Herbaceous-Shrub Steppe, and Herbaceous-Tree Savanna.			5	1	4
Target condition	Viewed remotely, average shrub cover over the stand area is high ($\geq$90%). There is high diversity in vertical structure (i.e. tall shrub layer 25%, emergent trees 5%) resulting in high fruit production. Field layer (<1m) is >90% closed, with most cover contributed by shrubs	5				
Near target condition	Average shrub cover over the stand area is relatively high (>70-90%). Diversity of vertical structure may be somewhat variable, but overall fruit production is high. Field layer is >70% closed. Herbaceous cover of field layer may contribute up to 25% cover	4				
Sub-target condition	Remotely viewed shrub cover is partially open (50-70%). Herbaceous cover of patches not occupied by shrubs is generally greater than 75% and exceeding 0.5m in height.	3				
Highly altered	Remotely viewed shrub cover is open (25-50%). Herbaceous cover of patches not occupied by shrubs is generally greater than 50%, only partially exceeding 0.5m in height on average	2				
Degraded	Remotely viewed shrub cover is low (<25%). Herbaceous cover of open patches less than 25% cover and / or less than 0.5 m in height; areas of bare ground may be significant	1				
V2. Invasive Exotic Plants[9]	The percent cover of a selected set of exotic species that are considered invasive.			2	1	2
Target condition	No key invasive species present OR County level data shows no key invasives present.	5				
Near target condition	Key invasive species 1-2% cover OR County level data shows presence of 1 key invasive exotic species.	4				
Sub-target condition	Key invasive species 3- 5% OR GIS layers show actual mapped key invasive exotic species overlap site boundaries, OR County level data shows presence of 2-3 key invasive exotic species.	3				
Highly altered	Key invasive species 5-25% OR GIS layers show actual mapped key invasive exotic patches that overlap >10% of the site boundaries, OR County level data shows presence of 4-5 key invasive exotic species.	2				
Degraded	Key invasive species >25% OR GIS layers show actual mapped key invasive exotic species patches that overlap >25% of the site boundaries., OR County level data shows presence of more than 5 species of key invasive exotic species.	1				

---

[8] Measurement of shrub cover was restricted to the tall shrub portion of the management unit, 5.25 acres measured on 2008 aerial photography.

[9] High cover of *Frangula alnus, Lonicera morrowi,* and *Robinia pseudoacacia* not measured but presumed to be greater than 5%, based on field estimate.

Table 2 Ecological Integrity Index for Parker River National Wildlife Refuge Shrubland Unit (continued)

V3. Vegetation Composition[10]	An assessment of the overall species composition and diversity, of the dominant vegetation layer, and evidence of specific species diseases or mortality.		3	1	3
Target condition	Vegetation is at target condition in species present and their proportions. Dominant vegetation layer is composed of all native species, and all indicator/diagnostic species are present.	5			
Near target condition	Vegetation is at or close to target condition in species present and their proportions. Dominant vegetation layer may be composed of some native species reflective of past disturbance (e.g., pioneer or early successional species) and exotic plants are low in abundance. Some indicator/diagnostic species may be absent.	4			
Sub-target condition	Vegetation is different from target condition in species diversity or proportions, but still largely composed of native species characteristic of the type. This may include weedy (pioneer, early successional) native species that develop after clearcutting or clearing. Exotics may be common, but not dominant. Invasive species may be present in low numbers. Many indicator/diagnostic species may be absent.	3			
Highly altered	Vegetation altered from target in composition. Expected strata are unnaturally absent, or composed of exotic species, or composed of planted stands of non-characteristic species, or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent; invasive species are present in quantity and require great effort to remove.	2			
Degraded	Vegetation severely altered from target in composition. Expected strata are unnaturally absent or dominated by exotic species or composed of planted stands of non-characteristic species or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent, and / or invasive species are intractable by reasonably cost-effective means.	1			
V4. Relative Percent Cover of Native Plant Species (opt.)	The relative percent cover of the plant species that are native to the region with respect to total vegetation cover.		4	1	4
Target condition	>98% relative cover of native plant species	5			
Near target condition	85-97% relative cover of native plant species	4			
Sub-target condition	60-84% relative cover of native plant species	3			
Highly altered	45-59% relative cover of native plant species	2			
Degraded	<45% relative cover of native plant species	1			

---

[10] Relatively high cover of invasive species suggests sub-reference condition. More precise measures are necessary to determine baseline for monitoring.

Table 2 Ecological Integrity Index for Parker River National Wildlife Refuge Shrubland Unit (continued)

V5. Vegetation Stressors Checklist[11]	Use VEGETATION (BIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)			2 (1)	3	1	3
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

SOIL / SUBSTRATE

S1. Soil/Substrate Condition	This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.				5	1	4
Target condition	No Apparent Soil Surface Modifications	5				
Sub-target condition	Past Soil Surface Modification but Recovered; OR Recent but Minor Modifications	4				
Highly altered	Recovering OR Recent and Moderate Soil Surface Modifications	3				
Degraded	Recent and Severe Soil Surface Modifications	1				

S2. On-Site Land Use[12]	Use 'Land Use Index Worksheet' tab.			0.965	4	1	5
Target condition	Land Use Index = 1.0-0.95	5				
Sub-target condition	Land Use Index = 0.80-0.95	4				
Highly altered	Land Use Index = 0.4-0.80	3				
Degraded	Land Use Index = < 0.4	1				

S3. Soils/Substrate Stressors Checklist[13]	Use SOIL / SUBSTRATE (ABIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)			1 (1)	4	1	4
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

---

[11] Vegetation stressors include minor vegetation removal (<10% of unit), and lack of effective treatment of invasive species (>10% of unit)

[12] Onsite land use measured on 2008 aerial photograph: 5% vegetation conversion (apparently cleared area at southern portion of unit); 95% natural area

[13] Soil stressors included: physical disturbance of soil / substrate (<10% of unit)

Table 2 Ecological Integrity Index for Parker River National Wildlife Refuge Shrubland Unit (concluded)

SUMMARY	Attribute			Overall
MAJOR ATTRIBUTE	**Score**	**Rating**	**Weight**	**Score**
Landscape Context	-	#N/A	1	
Size	-	#N/A	1	
Vegetation	3.2	C	1	
Soils/Substrate	4.3333	B	1	
Hydrology	-	#N/A	0	
OVERALL SCORE				3.6
OVERALL RATING (Index of Ecological Integrity)				B
OVERALL RATING DESCRIPTION				Sustainable

Table 3 Ecological Integrity Index for Ninigret National Wildlife Refuge Shrubland

VEGETATION						
V1. Vegetation Structure[14]	An assessment of the overall structural complexity of the dominant vegetation layer, including the density, stem size, and canopy cover relative to target conditions. Specific variants are provided for Forest, Woodland, Shrubland/Dwarf-shrubland - closed, Shrubland/Dwarf-shrubland-open, Herbaceous-Grassland&Meadow, Herbaceous-Shrub Steppe, and Herbaceous-Tree Savanna.			2	1	2
Target condition	Viewed remotely, average shrub cover over the stand area is high (≥90%). There is high diversity in vertical structure (i.e. tall shrub layer 25%, emergent trees 5%) resulting in high fruit production. Field layer (<1m) is >90% closed, with most cover contributed by shrubs	5				
Near target condition	Average shrub cover over the stand area is relatively high (>70-90%). Diversity of vertical structure may be somewhat variable, but overall fruit production is high. Field layer is >70% closed. Herbaceous cover of field layer may contribute up to 25% cover	4				
Sub-target condition	Remotely viewed shrub cover is partially open (50-70%). Herbaceous cover of patches not occupied by shrubs is generally greater than 75% and exceeding 0.5m in height.	3				
Highly altered	Remotely viewed shrub cover is open (25-50%). Herbaceous cover of patches not occupied by shrubs is generally greater than 50%, only partially exceeding 0.5m in height on average	2				
Degraded	Remotely viewed shrub cover is low (<25%). Herbaceous cover of open patches less than 25% cover and / or less than 0.5 m in height; areas of bare ground may be significant	1				
V2. Invasive Exotic Plants[15]	The percent cover of a selected set of exotic species that are considered invasive.			2	1	2
Target condition	No key invasive species present OR County level data shows no key invasives present.	5				
Near target condition	Key invasive species 1-2% cover OR County level data shows presence of 1 key invasive exotic species.	4				
Sub-target condition	Key invasive species 3- 5% OR GIS layers show actual mapped key invasive exotic species overlap site boundaries, OR County level data shows presence of 2-3 key invasive exotic species.	3				
Highly altered	Key invasive species 5-25% OR GIS layers show actual mapped key invasive exotic patches that overlap >10% of the site boundaries, OR County level data shows presence of 4-5 key invasive exotic species.	2				
Degraded	Key invasive species >25% OR GIS layers show actual mapped key invasive exotic species patches that overlap >25% of the site boundaries., OR County level data shows presence of more than 5 species of key invasive exotic species.	1				

---

[14] Measured shrub cover from aerial photography, approximately 51% cover, but understory not well developed in some areas
[15] Estimated from map of exotics provided by USFWS

Table 3 Ecological Integrity Index for Ninigret National Wildlife Refuge Shrubland (continued)

V3. Vegetation Composition[16]	An assessment of the overall species composition and diversity, of the dominant vegetation layer, and evidence of specific species diseases or mortality.		2	1	2
Target condition	Vegetation is at target condition in species present and their proportions. Dominant vegetation layer is composed of all native species, and all indicator/diagnostic species are present.	5			
Near target condition	Vegetation is at or close to target condition in species present and their proportions. Dominant vegetation layer may be composed of some native species reflective of past disturbance (e.g., pioneer or early successional species) and exotic plants are low in abundance. Some indicator/diagnostic species may be absent.	4			
Sub-target condition	Vegetation is different from target condition in species diversity or proportions, but still largely composed of native species characteristic of the type. This may include weedy (pioneer, early successional) native species that develop after clearcutting or clearing. Exotics may be common, but not dominant. Invasive species may be present in low numbers. Many indicator/diagnostic species may be absent.	3			
Highly altered	Vegetation altered from target in composition. Expected strata are unnaturally absent, or composed of exotic species, or composed of planted stands of non-characteristic species, or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent; invasive species are present in quantity and require great effort to remove.	2			
Degraded	Vegetation severely altered from target in composition. Expected strata are unnaturally absent or dominated by exotic species or composed of planted stands of non-characteristic species or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent, and / or invasive species are intractable by reasonably cost-effective means.	1			
V4. Relative Percent Cover of Native Plant Species (opt.)[17]	The relative percent cover of the plant species that are native to the region with respect to total vegetation cover.		2	1	1
Target condition	>98% relative cover of native plant species	5			
Near target condition	85-97% relative cover of native plant species	4			
Sub-target condition	60-84% relative cover of native plant species	3			
Highly altered	45-59% relative cover of native plant species	2			
Degraded	<45% relative cover of native plant species	1			

[16] Composition in shrubland, except for *Celastrus*, is primarily native species. Composition of old field is primarily non-native.
[17] Native cover for area west of runway is considerably higher, but on average, native cover is approximately 47%

Table 3 Ecological Integrity Index for Ninigret National Wildlife Refuge Shrubland (continued)

V5. Vegetation Stressors Checklist[18]	Use VEGETATION (BIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)			4 (4)	2	1	2
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Altered / Degraded	4 stressor listed and >2 have significant effects	2				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

SOIL / SUBSTRATE

S1. Soil/Substrate Condition	This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.				3	1	3
Target condition	No Apparent Soil Surface Modifications	5				
Sub-target condition	Past Soil Surface Modification but Recovered; OR Recent but Minor Modifications	4				
Highly altered	Recovering OR Recent and Moderate Soil Surface Modifications	3				
Degraded	Recent and Severe Soil Surface Modifications	1				

S2. On-Site Land Use	Use 'Land Use Index Worksheet' tab.			0.659	3	1	3
Target condition	Land Use Index = 1.0-0.95	5				
Sub-target condition	Land Use Index = 0.80-0.95	4				
Highly altered	Land Use Index = 0.4-0.80	3				
Degraded	Land Use Index = < 0.4	1				

S3. Soils/Substrate Stressors Checklist[19]	Use SOIL / SUBSTRATE (ABIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)			1 (1)	3	1	3
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and / or 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

---

[18] Vegetation stressors included excessive deer browse, history of vegetation removal on runway, mowing, and non- or ineffective treatment of invasive species
[19] Soil stressor includes history of soil disturbance from runway

Table 3 Ecological Integrity Index for Ninigret National Wildlife Refuge Shrubland (concluded)

SUMMARY	Attribute			Overall
MAJOR ATTRIBUTE	**Score**	**Rating**	**Weight**	**Score**
Landscape Context	-	#N/A	1	
Size	-	#N/A	1	
Vegetation	2	D	1	
Soils/Substrate	3	C	1	
Hydrology	-	#N/A	0	
OVERALL SCORE				2.5
OVERALL RATING (Index of Ecological Integrity)				C
OVERALL RATING DESCRIPTION				Transitioning

Great Meadows

Baseline indices were calculated for Hunter field and Rice's Barn field together, as their restoration will contribute to the same wetland shrubland bordering the river (Table 4). Both of these fields vary considerably from the target vegetation type, and as such were ranked as "D", degraded. The overall numerical index was 1.87.

At Sandy field, only the sandy portion dominated by *Schizachyrium scoparium* and *Eragrostis spectabilis* was evaluated. However, the species composition, and less so, the vegetation structure, more strongly resemble the target vegetation. This field was also ranked "C", transitioning, with an overall numerical index of 2.53 (Table 5).

Rachel Carson

The baseline index was calculated for all three old fields as a unit (Table 6). As a recovering old field, it resembles desired vegetation only in part. The overall rank was "C", transitioning, and the numerical index was 2.74.

Table 4 Ecological Integrity Index for Hunter Field and Rice's Barn Field

VEGETATION					
V1. Vegetation Structure	An assessment of the overall structural complexity of the dominant vegetation layer, including the density, stem size, and canopy cover relative to target conditions. Specific variants are provided for Forest, Woodland, Shrubland/Dwarf-shrubland - closed, Shrubland/Dwarf-shrubland-open, Herbaceous-Grassland&Meadow, Herbaceous-Shrub Steppe, and Herbaceous-Tree Savanna.		1	1	1
Target condition	Viewed remotely, average shrub cover over the stand area is high (>90%). There is high diversity in vertical structure (i.e. tall shrub layer 25%, emergent trees 5%) resulting in high fruit production. Field layer (<1m) is >90% closed, with most cover contributed by shrubs	5			
Near target condition	Average shrub cover over the stand area is relatively high (>70-90%). Diversity of vertical structure may be somewhat variable, but overall fruit production is high. Field layer is >70% closed. Herbaceous cover of field layer may contribute up to 25% cover	4			
Sub-target condition	Remotely viewed shrub cover is partially open (50-70%). Herbaceous cover of patches not occupied by shrubs is generally greater than 75% and exceeding 0.5m in height.	3			
Highly altered	Remotely viewed shrub cover is open (25-50%). Herbaceous cover of patches not occupied by shrubs is generally greater than 50%, only partially exceeding 0.5m in height on average	2			
Degraded	Remotely viewed shrub cover is low (<25%). Herbaceous cover of open patches less than 25% cover and / or less than 0.5 m in height; areas of bare ground may be significant	1			
V2. Invasive Exotic Plants[20]	The percent cover of a selected set of exotic species that are considered invasive.		1	1	1
Target condition	No key invasive species present OR County level data shows no key invasives present.	5			
Near target condition	Key invasive species 1-2% cover OR County level data shows presence of 1 key invasive exotic species.	4			
Sub-target condition	Key invasive species 3- 5% OR GIS layers show actual mapped key invasive exotic species overlap site boundaries, OR County level data shows presence of 2-3 key invasive exotic species.	3			
Highly altered	Key invasive species 5-25% OR GIS layers show actual mapped key invasive exotic patches that overlap >10% of the site boundaries, OR County level data shows presence of 4-5 key invasive exotic species.	2			
Degraded	Key invasive species >25% OR GIS layers show actual mapped key invasive exotic species patches that overlap >25% of the site boundaries., OR County level data shows presence of more than 5 species of key invasive exotic species.	1			

---

[20] Measurement from map of invasives provided by USFWS

Table 4 Ecological Integrity Index for Hunter Field and Rice's Barn Field (continued)

V3. Vegetation Composition	An assessment of the overall species composition and diversity, of the dominant vegetation layer, and evidence of specific species diseases or mortality.		1	1	1
Target condition	Vegetation is at target condition in species present and their proportions. Dominant vegetation layer is composed of all native species, and all indicator/diagnostic species are present.	5			
Near target condition	Vegetation is at or close to target condition in species present and their proportions. Dominant vegetation layer may be composed of some native species reflective of past disturbance (e.g., pioneer or early successional species) and exotic plants are low in abundance. Some indicator/diagnostic species may be absent.	4			
Sub-target condition	Vegetation is different from target condition in species diversity or proportions, but still largely composed of native species characteristic of the type. This may include weedy (pioneer, early successional) native species that develop after clearcutting or clearing. Exotics may be common, but not dominant. Invasive species may be present in low numbers. Many indicator/diagnostic species may be absent.	3			
Highly altered	Vegetation altered from target in composition. Expected strata are unnaturally absent, or composed of exotic species, or composed of planted stands of non-characteristic species, or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent; invasive species are present in quantity and require great effort to remove.	2			
Degraded	Vegetation severely altered from target in composition. Expected strata are unnaturally absent or dominated by exotic species or composed of planted stands of non-characteristic species or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent, and / or invasive species are intractable by reasonably cost-effective means.	1			
V4. Relative Percent Cover of Native Plant Species (opt.)[21]	The relative percent cover of the plant species that are native to the region with respect to total vegetation cover.		2	1	2
Target condition	>98% relative cover of native plant species	5			
Near target condition	85-97% relative cover of native plant species	4			
Sub-target condition	60-84% relative cover of native plant species	3			
Highly altered	45-59% relative cover of native plant species	2			
Degraded	<45% relative cover of native plant species	1			

---

[21] Native wetland species occur in more seasonally flooded areas of study site

Table 4 Ecological Integrity Index for Hunter Field and Rice's Barn Field (continued)

V5. Vegetation Stressors Checklist[22]	Use VEGETATION (BIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)		4 (3)	2	1	2
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Altered / Degraded	4 stressor listed and >2 have significant effects	2				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

SOIL / SUBSTRATE

S1. Soil/Substrate Condition[23]	This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.			3	1	3
Target condition	No Apparent Soil Surface Modifications	5				
Sub-target condition	Past Soil Surface Modification but Recovered; OR Recent but Minor Modifications	4				
Highly altered	Recovering OR Recent and Moderate Soil Surface Modifications	3				
Degraded	Recent and Severe Soil Surface Modifications	1				

S2. On-Site Land Use[24]	Use 'Land Use Index Worksheet' tab.		0.5	1	1	1
Target condition	Land Use Index = 1.0-0.95	5				
Sub-target condition	Land Use Index = 0.80-0.95	4				
Highly altered	Land Use Index = 0.4-0.80	3				
Degraded	Land Use Index = < 0.4	1				

S3. Soils/Substrate Stressors Checklist[25]	Use SOIL / SUBSTRATE (ABIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)		1 (1)	3	1	3
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and / or 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

---

[22] Vegetation stressors include mowing, herbivory by deer, shrub removal, removal of woody debris, ineffective treatment of invasive exotic species

[23] Soil condition considered highly altered due to impacts of heavy machinery

[24] on-site land use was judged to be 100% old field

[25] Soil stressors include disturbances as a result of heavy machinery on wetland soils.

Table 4 Ecological Integrity Index for Hunter Field and Rice's Barn Field (concluded)

SUMMARY	Attribute			Overall
MAJOR ATTRIBUTE	**Score**	**Rating**	**Weight**	**Score**
Landscape Context	-	#N/A	1	
Size	-	#N/A	1	
Vegetation	1.4	D	1	
Soils/Substrate	2.3	C	1	
Hydrology	-	#N/A	0	
OVERALL SCORE				1.87
OVERALL RATING (Index of Ecological Integrity)				D
OVERALL RATING DESCRIPTION				Degraded

Table 5 Ecological Integrity Index for Sandy Field

VEGETATION					
V1. Vegetation Structure	An assessment of the overall structural complexity of the dominant vegetation layer, including the density, stem size, and canopy cover relative to target conditions. Specific variants are provided for Forest, Woodland, Shrubland/Dwarf-shrubland - closed, Shrubland/Dwarf-shrubland-open, Herbaceous-Grassland&Meadow, Herbaceous-Shrub Steppe, and Herbaceous-Tree Savanna.		1	1	1
Target condition	Viewed remotely, average shrub cover over the stand area is high ($\geq$90%). There is high diversity in vertical structure (i.e. tall shrub layer 25%, emergent trees 5%) resulting in high fruit production. Field layer (<1m) is >90% closed, with most cover contributed by shrubs	5			
Near target condition	Average shrub cover over the stand area is relatively high (>70-90%). Diversity of vertical structure may be somewhat variable, but overall fruit production is high. Field layer is >70% closed. Herbaceous cover of field layer may contribute up to 25% cover	4			
Sub-target condition	Remotely viewed shrub cover is partially open (50-70%). Herbaceous cover of patches not occupied by shrubs is generally greater than 75% and exceeding 0.5m in height.	3			
Highly altered	Remotely viewed shrub cover is open (25-50%). Herbaceous cover of patches not occupied by shrubs is generally greater than 50%, only partially exceeding 0.5m in height on average	2			
Degraded	Remotely viewed shrub cover is low (<25%). Herbaceous cover of open patches less than 25% cover and / or less than 0.5 m in height; areas of bare ground may be significant	1			
V2. Invasive Exotic Plants	The percent cover of a selected set of exotic species that are considered invasive.		3	1	3
Target condition	No key invasive species present OR County level data shows no key invasives present.	5			
Near target condition	Key invasive species 1-2% cover OR County level data shows presence of 1 key invasive exotic species.	4			
Sub-target condition	Key invasive species 3- 5% OR GIS layers show actual mapped key invasive exotic species overlap site boundaries, OR County level data shows presence of 2-3 key invasive exotic species.	3			
Highly altered	Key invasive species 5-25% OR GIS layers show actual mapped key invasive exotic patches that overlap >10% of the site boundaries, OR County level data shows presence of 4-5 key invasive exotic species.	2			
Degraded	Key invasive species >25% OR GIS layers show actual mapped key invasive exotic species patches that overlap >25% of the site boundaries., OR County level data shows presence of more than 5 species of key invasive exotic species.	1			

Table 5 Ecological Integrity Index for Sandy Field (continued)

V3. Vegetation Composition[26]	An assessment of the overall species composition and diversity, of the dominant vegetation layer, and evidence of specific species diseases or mortality.			3	1	3
Target condition	Vegetation is at target condition in species present and their proportions. Dominant vegetation layer is composed of all native species, and all indicator/diagnostic species are present.	5				
Near target condition	Vegetation is at or close to target condition in species present and their proportions. Dominant vegetation layer may be composed of some native species reflective of past disturbance (e.g., pioneer or early successional species) and exotic plants are low in abundance. Some indicator/diagnostic species may be absent.	4				
Sub-target condition	Vegetation is different from target condition in species diversity or proportions, but still largely composed of native species characteristic of the type. This may include weedy (pioneer, early successional) native species that develop after clearcutting or clearing. Exotics may be common, but not dominant. Invasive species may be present in low numbers. Many indicator/diagnostic species may be absent.	3				
Highly altered	Vegetation altered from target in composition. Expected strata are unnaturally absent, or composed of exotic species, or composed of planted stands of non-characteristic species, or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent; invasive species are present in quantity and require great effort to remove.	2				
Degraded	Vegetation severely altered from target in composition. Expected strata are unnaturally absent or dominated by exotic species or composed of planted stands of non-characteristic species or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent, and / or invasive species are intractable by reasonably cost-effective means.	1				
V4. Relative Percent Cover of Native Plant Species (opt.)[27]	The relative percent cover of the plant species that are native to the region with respect to total vegetation cover.			2	1	2
Target condition	>98% relative cover of native plant species	5				
Near target condition	85-97% relative cover of native plant species	4				
Sub-target condition	60-84% relative cover of native plant species	3				
Highly altered	45-59% relative cover of native plant species	2				
Degraded	<45% relative cover of native plant species	1				

---

[26] Native shrubs were absent, but native grasses provided significant cover
[27] Relative cover of shrub component lowered this value despite high cover of native grasses

Table 5 Ecological Integrity Index for Sandy Field (continued)

Metric	Description					
V5. Vegetation Stressors Checklist[28]	Use VEGETATION (BIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)		2 (1)	3	1	3
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Altered / Degraded	4 stressor listed and >2 have significant effects	2				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

SOIL / SUBSTRATE

Metric	Description					
S1. Soil/Substrate Condition[29]	This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.			4	1	3
Target condition	No Apparent Soil Surface Modifications	5				
Sub-target condition	Past Soil Surface Modification but Recovered; OR Recent but Minor Modifications	4				
Highly altered	Recovering OR Recent and Moderate Soil Surface Modifications	3				
Degraded	Recent and Severe Soil Surface Modifications	1				
S2. On-Site Land Use[30]	Use 'Land Use Index Worksheet' tab.		0.5	1	1	1
Target condition	Land Use Index = 1.0-0.95	5				
Sub-target condition	Land Use Index = 0.80-0.95	4				
Highly altered	Land Use Index = 0.4-0.80	3				
Degraded	Land Use Index = < 0.4	1				
S3. Soils/Substrate Stressors Checklist[31]	Use SOIL / SUBSTRATE (ABIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)		1 (0)	4	1	4
Target condition	No stressors listed	5				
Sub-target condition	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Highly altered	2-4 stressors listed, and / or 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Degraded	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

---

[28] Vegetation stressors included mowing; low cover of invasives on the sandy section of this field

[29] Minor soil modifications presumed from repeated mowing

[30] On-site land use 100% old field

[31] Minor soil modifications presumed from repeated mowing

Table 5 Ecological Integrity Index for Sandy Field (concluded)

SUMMARY	Attribute			Overall
MAJOR ATTRIBUTE	Score	Rating	Weight	Score
Landscape Context	-	#N/A	1	
Size	-	#N/A	1	
Vegetation	2.4	C	1	
Soils/Substrate	2.7	C	1	
Hydrology	-	#N/A	0	
OVERALL SCORE				2.53
OVERALL RATING (Index of Ecological Integrity)				C
OVERALL RATING DESCRIPTION				Transitioning

Table 6 Land Use Index for Rachel Carson old fields (Cutts 1, 2 and 3)

Major Attribute	Metric	Point Scale	Field Value	Field Score	Metric Weight[32]	Weighted Field Score
VEGETATION						
V1. Vegetation Structure [33]	An assessment of the overall structural complexity of the dominant vegetation layer, including the density, stem size, and canopy cover relative to target conditions. Specific variants are provided for Forest, Woodland, Shrubland/Dwarf-shrubland - closed, Shrubland/Dwarf-shrubland-open, Herbaceous-Grassland&Meadow, Herbaceous-Shrub Steppe, and Herbaceous-Tree Savanna.			1	3	3
Target condition	Viewed remotely, average shrub cover over the stand area is high (>90%). There is high diversity in vertical structure (i.e. tall shrub layer 25%, emergent trees 5%) resulting in high fruit production. Field layer (<1m) is >90% closed, with most cover contributed by shrubs	5				
Near target condition	Average shrub cover over the stand area is relatively high (>70-90%). Diversity of vertical structure may be somewhat variable, but overall fruit production is high. Field layer is >70% closed. Herbaceous cover of field layer may contribute up to 25% cover	4				
Sub-target condition	Remotely viewed shrub cover is partially open (50-70%). Herbaceous cover of patches not occupied by shrubs is generally greater than 75% and exceeding 0.5m in height.	3				
Highly altered	Remotely viewed shrub cover is open (25-50%). Herbaceous cover of patches not occupied by shrubs is generally greater than 50%, only partially exceeding 0.5m in height on average	2				
Degraded	Remotely viewed shrub cover is low (<25%). Herbaceous cover of open patches less than 25% cover and / or less than 0.5 m in height; areas of bare ground may be significant	1				
V2. Invasive Exotic Plants[34]	The percent cover of a selected set of exotic species that are considered invasive.			3	1	3
Sustainable+ (A)	No key invasive species present OR County level data shows no key invasives present.	5				
Sustainable (B)	Key invasive species 1-2% cover OR County level data shows presence of 1 key invasive exotic species.	4				
Transitioning (C)	Key invasive species 3- 5% OR GIS layers show actual mapped key invasive exotic species overlap site boundaries, OR County level data shows presence of 2-3 key invasive exotic species.	3				
Degraded (D)	Key invasive species 5-25% OR GIS layers show actual mapped key invasive exotic patches that overlap >10% of the site boundaries, OR County level data shows presence of 4-5 key invasive exotic species.	2				
Very Degraded (E)	Key invasive species >25% OR GIS layers show actual mapped key invasive exotic species patches that overlap >25% of the site boundaries., OR County level data shows presence of more than 5 species of key invasive exotic species.	1				

---

[32] Because vegetation structure is relatively more important than are the other factors for management of New England cottontail, this factor was weighted by a factor of 3.

[33] measured woody vegetation on spring aerial photography; shrub cover includes trees and is probably generous. Vegetation structure is weighted triple the other factors due to NEC need for high stem density

[34] percent cover of exotics was noted in the field and difficult to extrapolate to the entire site, so should be considered a very rough estimate.

Table 6 Land Use Index for Rachel Carson old fields (Cutts 1, 2 and 3) (continued)

Metric	Description	Score	Cut 1	Cut 2	Cut 3
V3. Vegetation Composition	An assessment of the overall species composition and diversity, of the dominant vegetation layer, and evidence of specific species diseases or mortality.		1	1	1
Sustainable (A,B)	Vegetation is at or close to target condition in species present and their proportions. Dominant vegetation layer may be composed of some native species reflective of past degradation (e.g., pioneer or early successional species) and exotic plants are low in abundance. Some indicator/diagnostic species may be absent.	5			
Transitioning (C)	Vegetation is different from target condition in species diversity or proportions, but still largely composed of native species characteristic of the type. This may include weedy (pioneer, early successional) native species that develop after clearcutting or clearing. Exotics may be common, but not dominant. Many indicator/diagnostic species may be absent.	3			
Degraded (D)	Vegetation severely altered from target in composition. Expected strata are unnaturally absent or dominated by exotic species or composed of planted stands of non-characteristic species or inappropriately composed of a single species. Most or all indicator/diagnostic species are absent.	1			
V4. Relative Percent Cover of Native Plant Species (opt.)	The relative percent cover of the plant species that are native to the region with respect to total vegetation cover.		3 / 1	1	1
Sustainable+ (A)	>95% relative cover of native plant species	5			
Sustainable (B)	80-94% relative cover of native plant species	4			
Transitioning (C)	50-79% relative cover of native plant species	3			
Degraded (D)	<50% relative cover of native plant species	1			
V5. Vegetation Stressors Checklist[35]	Use VEGETATION (BIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)		3 (3) / 3	1	3
Sustainable+ (A)	No stressors listed	5			
Sustainable (B)	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4			
Transitioning (C)	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3			
Degraded (D)	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1			

SOIL / SUBSTRATE

Metric	Description	Score	Cut 1	Cut 2	Cut 3
S1. Soil/Substrate Condition	This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.		4	1	4
Sustainable+ (A)	No Apparent Soil Surface Modifications	5			
Sustainable (B)	Past Soil Surface Modification but Recovered; OR Recent but Minor Modifications	4			
Transitioning (C)	Recovering OR Recent and Moderate Soil Surface Modifications	3			
Degraded (D)	Recent and Severe Soil Surface Modifications	1			

---

[35] Stressors include mowing, past tree and shrub removal, and ineffective treatment of exotics

Table 6 Land Use Index for Rachel Carson old fields (Cutts 1, 2 and 3) (continued)

S2. On-Site Land Use[36]	Use 'Land Use Index Worksheet' tab.		0.5	3	1	3
Sustainable+ (A)	Land Use Index = 1.0-0.95	5				
Sustainable (B)	Land Use Index = 0.80-0.95	4				
Transitioning (C)	Land Use Index = 0.4-0.80	3				
Degraded (D)	Land Use Index = < 0.4	1				
S3. Soils/Substrate Stressors Checklist[37]	Use SOIL / SUBSTRATE (ABIOTIC CONDITION) checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)		0 (1)	4	1	4
Sustainable+ (A)	No stressors listed	5				
Sustainable (B)	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Transitioning (C)	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Degraded (D)	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

HYDROLOGY						
H1-n. Hydrologic Alterations (non – riparian only)[38]	An assessment of the various stressors that impact hydrologic condition. Applies to non-riverine systems.			3	2	6
Sustainable+ (A)	No alterations. No dikes, diversions, ditches, flow additions, pugging, fill, or wells present in assessment area that restricts, redirects, or lowers flow or water table.	5				
Sustainable (B)	Low intensity alteration such as roads at/near grade, pugging, small diversion or ditches (< 1 ft. deep) or small amount of flow additions, or a few wells.	4				
Transitioning (C)	Moderate intensity alteration such as 2-lane road, low dikes, pugging, roads w/culverts adequate for stream flow, medium diversion or ditches (1-3 ft. deep) or moderate flow additions, or moderate number of wells on or off site.	3				
Degraded (D)	High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable of lowering water table, large amount of fill, or high amounts of flow additions, groundwater and well pumping.	1				
H4. Hydrologic Stressors Checklist[39]	Use HYDROLOGY checklist on 'Stressor Checklists' tab. (Field value is shown as [total # of stressors (# significant)].)		2 (1)	3	1	3
Sustainable+ (A)	No stressors listed	5				
Sustainable (B)	1-3 stressors listed, but none have significant effect (i.e. they occur over <10% of the area).	4				
Transitioning (C)	2-4 stressors listed, and 1-2 have significant effects (i.e. they occur over >10% of the area).	3				
Degraded (D)	More than 4 stressors listed, and 2 or more have significant effects (i.e. they occur over >10% of the area).	1				

[36] land use index assumes 100% of site is recovering old field.

[37] Soil stressor includes past physical disturbance caused by machinery

[38] hydrologic alterations include ditching in low areas

[39] hydrologic stressors refer to restricted tidal flow imposed by the road fronting the site; inclusion of these stressors on vegetation of minor importance to the target species may be unnecessary

Table 6 Land Use Index for Rachel Carson old fields (Cutts 1, 2 and 3) (concluded)

SUMMARY	Attribute			Overall
MAJOR ATTRIBUTE	Score	Rating	Weight	Score
Landscape Context	-	#N/A	1.000	
Size	-	#N/A	1.000	
Vegetation	1.571	D	1.000	
Soils/Substrate	3.667	B	1.000	
Hydrology	3.000	C	1.000	
OVERALL SCORE				2.746
OVERALL RATING (Index of Ecological Integrity)				C
OVERALL RATING DESCRIPTION			Transitioning	

Discussion

Target Vegetation: Parker River and Ninigret

In general, descriptions from presettlement vegetation provide a valuable source of information in developing criteria for the targeted community structure and composition. However, the Successional Maritime Forest occupying Parker River today is not likely to have been a major component of presettlement vegetation. McDonnell (1979) provides a summary of descriptions derived from historical records. The backdunes now supporting Successional Maritime Forest supported a pine forest extending the length of the island. McDonnell theorizes that pines were either removed by island inhabitants after the late eighteenth century, or they were felled by a catastrophic storm. The island was essentially treeless by the early nineteenth century. Small patches of a pitch-pine dominated community occur today on the island, and likely reflects the native vegetation to a varying degree. This type is mapped as CEGL006381 on the vegetation map and is classified as *Pinus rigida - Quercus coccinea / Vaccinium pallidum - (Morella pensylvanica)* Woodland (Pitch Pine – Oak Forest). This vegetation is nearly devoid of fleshy fruit-producing trees and shrubs, and restoration of this type to its former extent at Parker River would likely be counter to the objective of maintaining habitat for migratory birds. Historically, it is probable that both the Successional Maritime Forest and Pitch Pine – Oak Forest characterized coastal habitats across the northeast, with Pitch Pine – Oak Forest occurring in older stands, and Successional Maritime Forest arising in large canopy gaps following tree fall and disturbance by intense coastal storms. Revegetation of Parker River following the loss of the original pine community likely occurred as bird-dispersed seeds of early successional species became established in the absence of a seed source for pines and oaks. Maritime Successional Forest is not only a critical habitat for migratory birds, but is also likely to have been established and perpetuated by birds.

Both Parker River and Ninigret have established the management objective to maintain or increase migratory bird habitat. Fall migration in particular imposes considerable stress on birds, and an abundant food source is vital to increasing energy reserves. Coastal shrub habitats, characterized by fleshy fruit-producing shrubs, provide these needed energy reserves in the form of fruits for migratory birds in the northeast (Parrish 1997). It follows that the desired vegetation type is one that is dominated by fleshy fruit-producing shrubs, or Successional Maritime Forest (*Prunus serotina - Sassafras albidum - Amelanchier canadensis - Quercus velutina / Smilax rotundifolia* Forest). This vegetation is abundant at both refuges. The NVC description of this vegetation is described below (NatureServe 2009)

Successional Maritime Forest ranges along the coast from southern Maine to Delaware. It occurs on sheltered backdunes, bluffs, or more interior coastal areas not directly influenced by overwash but affected by salt spray and wind-pruning. Vegetation in these sheltered areas is sometimes referred to as "sunken forest." This name refers to the topographic position of these examples, which are found in large depressions, lower in elevation (by 1-3 m) than the interdunes. These examples are shielded from strong prevailing winds and salt spray, which permits lush growth of broadleaf shrub and vine species. Soils are coarse,

well-drained sand subject to considerable shifting during coastal storms, or till and sand deposits of terminal moraines. Physiognomy is variable and ranges from closed-canopy forest to open woodland to dense tall shrubland, and may be more accurately called scrub. Trees found in this community are usually stunted and flat-topped; the canopy may be only 3-7 m tall. Dominant trees vary locally and include *Prunus serotina, Sassafras albidum*, and *Amelanchier canadensis*, with admixtures of *Celtis occidentalis, Quercus velutina, Pinus rigida, Juniperus virginiana, Acer rubrum, Amelanchier stolonifera* (running serviceberry), and in southern occurrences *Quercus coccinea* (scarlet oak)*, Quercus falcata* (southern red oak)*, Liquidambar styraciflua* (sweet gum), and *Ilex opaca* (American holly). Additional shrub species may also contribute substantially to the canopy and include *Vaccinium corymbosum, Morella pensylvanica (= Myrica pensylvanica), Gaylussacia baccata, Viburnum dentatum*, and *Rosa virginiana* (Virginia rose). A true low shrub layer is generally not present. Lianas are common and can be dense in the canopy or the ground layer; species include *Parthenocissus quinquefolia, Toxicodendron radicans, Smilax rotundifolia*, and *Smilax glauca* (cat greenbrier). The understory is generally sparse with tree or vine seedlings plus herbaceous species, including *Aralia nudicaulis, Moehringia lateriflora (= Arenaria lateriflora), Maianthemum stellatum (= Smilacina stellata)* (starry false lily of the valley), and *Maianthemum canadense* (Canada mayflower). Several invasive species can be prevalent in this association, including *Lonicera morrowii, Lonicera japonica, Ligustrum vulgare* (European privet)*, Berberis vulgaris*, and *Celastrus orbiculata*.

Species of this association especially attractive to migratory birds include *Viburnum dentatum,* and *Parthenocissus quinquefolia. Morella pensylvanica* is also utilized by a lesser number of birds that can digest the wax. Fruits of these species are relatively high in fat content, and require ingestion of less volume than of fruits higher in carbohydrates (Smith et al. 2007). Other fleshy-fruit producing species attractive to birds include *Photina =Aronia) melanocarpa* (black choke berry)*, Sassafras albidum, Amelanchier canadensis, Smilax rotundifolia,* and *Toxicodendron radicans* (Baird 1980; Gill and Healey 1974)

Target Environmental Condition: Vegetation occurs in backdune hollows. Soil is characterized by a thick layer of leaf litter over deep well-drained sand and sandy loam. Absence or incidental occurrence of invasive / exotic species.

Target Dynamics: Diversity of vegetation structure is maintained by overwash and tree falls coastal storms and hurricanes.

Target Vegetation Structure and Composition: Structure varies considerably, with uneven heights of canopy trees to stimulate additional fruit production. In overall growth form, this vegetation is a tall shrubland, with a wind-pruned canopy. The tall shrub canopy is dominated by *Prunus serotina, Amelanchier canadensis,* and *Sassafras albidum*. Additional tree species that produce highly desirable fruits for birds include *Nyssa sylvatica* and *Juniperus virginiana.* Additional prominent fleshy fruit-producing shrubs include *Prunus virginiana, Photinia pyrifolia (=Aronia arbutifolia)* (red chokeberry), *Vitis* spp. (grape) and *Ilex verticillata*. The herbaceous layer ranges from sparse to dense, depending on the degree of canopy opening, and is characterized by *Aralia nudicaulis*

(wild sarsparilla), *Teucrium canadense, Smilax rotundifolia,* and *Toxicodendron radicans.* To increase high quality habitat for New England cottontail, very dense low shrub thickets comprised primarily of the native vines *Rubus* spp., *Smilax rotundifolia, Parthenocissus quinquefolia,* and *Toxicodendron radicans* would be highly desirable.

Target Average species composition of Successional Maritime Forest:[40]

Stratum	Lifeform	Species	Cover Range / Frequency
Tall Shrub	Broad-leaved deciduous tree	*Prunus serotina*	20-80% / common
Tall shrub	Broad-leaved deciduous tree	*Quercus velutina*	10-40% / common
Tall shrub	Broad-leaved deciduous tree	*Nyssa sylvatica*	10-30% / occasional
Tall shrub	Broad-leaved deciduous tree	*Sassafras albidum*	10-30% / occasional
Tall Shrub	Broad-leaved deciduous tree	*Quercus rubra*	2-5% / occasional
Tall Shrub	Broad-leaved deciduous tree	*Acer rubrum*	5-25% / occasional
Tall Shrub	Broad-leaved deciduous tree	*Celtis occidentalis*	5-25% / occasional
Tall Shrub	Broad-leaved deciduous shrub	*Amelanchier canadensis*	20–80% / common
Tall Shrub	Broad-leaved deciduous shrub	*Aronia melanocarpa*	20-30% / occasional
Short Shrub	Broad-leaved deciduous shrub	*Morella pensylvanica*	5-60% / common
Short shrub	Broad-leaved deciduous shrub	*Vaccinium pallidum*	35-60% / common
Short shrub	Broad-leaved deciduous shrub	*Gaylussacia baccata*	35-60% / common
Short shrub	Broad-leaved evergreen shrub	*Gaultheria procumbens*	5-10% / common
Herb / Field	Forb	*Polygonatum pubescens*	2-5% / occasional
Herb / Field	Forb	*Smilacina stellata*	2-50% / common
Herb / Field	Vine / Liana	*Smilax herbacea*	2-5% / rare
Herb / Field	Vine / Liana	*Smilax rotundifolia*	5-50% / common
Herb / Field	Forb	*Urtica dioica*	<1 – 1% / rare
Herb / Field	Forb	*Polygonum cilinode*	<1% / rare
Herb / Field	Forb	*Moehringia lateriflora*	1-25% / common

Target Vegetation: Great Meadows

Hunter Field and wetland edge of Rice's Barn field

Wetland shrublands have not been well studied in the NVC, and defining a naturally occurring target vegetation type poses some difficulty. Both sites are currently characterized by wetland soils, and are probably seasonally flooded. As such, the desired condition is not a true "shrub swamp" characterized by standing water for much of the growing season, as is typical in several NVC types such as *Alnus incana - Viburnum recognitum / Calamagrostis canadensis* Shrubland (Gray Alder - Arrow-wood / Bluejoint Shrub Swamp), *Alnus serrulata* Swamp Shrubland (Smooth Alder Swamp), and *Cephalanthus occidentalis - Decodon verticillatus* Shrubland (Northeastern Buttonbush Shrub Swamp). The vegetation at Hunter and Rice's Barn fields most resembles NVC type CEGL006576) *Cornus (amomum, sericea) - Viburnum dentatum - Rosa multiflora* Shrubland (Dogwood - Arrow-wood Successional Wet Shrubland), a successional type developed provisionally to describe wet shrublands following alteration in hydrology or other land use change. It is probable that this type occurs in a more natural condition on the

---

[40] Species list is drawn in large part from "shrub thicket" and "sunken forest" habitats of McDonnell 1979, as well as from vegetation plots taken in tall shrubland on Block Island, Rhode Island.

Sudbury River at Great Meadows. The wet shrubland originally mapped along the western edge of the river in the vicinity of all three study sites is more likely to be the Dog-wood – Arrow-wood Successional Wet Shrubland. It is incorrectly mapped as CEGL006512, *Myrica gale – Spiraea alba – Chamaedaphne calyculata* Shrubland, a poor fen type that occurs only rarely at Great Meadows.

The Dogwood – Arrowwood – Successional Wet Shrubland is floristically related to the commonly occurring swamp forest occurring at Great Meadows, called the *Acer rubrum - Fraxinus (pennsylvanica, americana) / Lindera benzoin / Symplocarpus foetidus* Forest (Red Maple Seepage Swamp, CEGL006406). This type is also incorrectly mapped as Red Maple – Black Gum Swamp (CEGL006156) on the original map. Figure 4 notes the assumed association types that were incorrectly mapped. Red Maple Seepage Swamp occurs adjacent to Rice's Barn Field and Hunter Field, and supports a well-developed shrub layer, including *Cornus amomum*, *Ilex verticillata*, and *Lindera benzoin*. I propose that the desired, or target vegetation at the lower slope of Rice's Barn Field and Hunter Field is the more natural expression of the Dogwood – Arrowwood Successional Wet Shrubland. The desired vegetation description of this type that follows draws on the shrubland component of Red Maple Seepage Swamp as well as the less documented Dogwood – Arrowwood Successional Shrub Wet Shrubland.

Target Environmental Condition: Hydrology remains intact with seasonal flooding and drawdown. Absence or incidental occurrence of invasive / exotic species. Soil disturbances are of natural origin only (occasional tip-up mounding).

Target Dynamics: Initial restoration efforts will require removal of exotic species and tree saplings, and some limited planting of native shrubs may be required. Once a vigorous stand of native shrubs becomes established, it casts dense cover that shades the understory and can persist for decades with little maintenance (Neiring and Egler1955; Tefft 2006).

Target Vegetation Structure and Composition: The target structure of the desired vegetation is a dense shrubland composed of fleshy fruit-producing native shrubs. Species attractive to birds include *Lindera benzoin, Cornus amomum, Viburnum dentatum, Parthenocissus quinquefolia,* and *Ilex verticillata* (Baird 1980; Suthers et al. 2000; Gill and Healey 1974). Diversity of canopy heights increases the area receiving sunlight, stimulating high fruit production (Baird 1980). The herbaceous layer may be well-developed in early spring, characterized by *Symplocarpus foetidus* (skunk cabbage), but as leaf-out occurs, the herbaceous layer is generally sparse and characterized by ferns *Osmunda sensibilis, Osmunda regalis* (royal fern)*, Thelypteris noveboracensis* (New York fern)*, Osmunda cinnamomea* (cinnamon fern)*.

Target Average Species Composition of Dogwood – Arrowwood Wet Shrubland[41]

Stratum	Lifeform	Species	Cover Range / Frequency
Tree Canopy	Broad-leaved deciduous tree	*Acer rubrum*	5-10% / uncommon
Tall Shrub	Broad-leaved deciduous shrub	*Lindera benzoin*	20 – 80% / common
Short Shrub	Broad-leaved deciduous shrub	*Cornus amomum*	20 – 80% / common
Short shrub	Broad-leaved deciduous shrub	*Ilex verticillata*	20 – 80% / common
Short shrub	Broad-leaved deciduous shrub	*Viburnum dentatum*	20 - 80% / common
Short shrub	Broad-leaved evergreen shrub	*Vaccinium corymbosum*	5-20% / occasional
Herb / Field	Vine / Liana	*Smilax rotundifolia*	5-50% / common
Herb / Field	Vine / Liana	*Vitis labrusca*	5-50% / common
Herb / Field	Vine / Liana	*Parthenocissus quinquefolia*	5-50% / common
Herb / Field	Forb	*Arisaema triphyllum*	5-10% /common
Herb / Field	Forb	*Symplocarpus foetidus*	25-40% /common
Herb / Field	Forb	*Impatiens capensis*	25-40% /common
Herb / Field	Fern or Fern Ally	*Onoclea sensibilis*	5-10% / common
Herb / Field	Fern or Fern Ally	*Thelypteris noveboracensis*	5-10% / common
Herb / Field	Fern or Fern Ally	*Osmunda cinnamomea*	5-10% / common
Herb / Field	Fern or Fern Ally	*Osmunda regalis*	5-10% / common
Herb / Field	Graminoid	*Calamagrostis canadensis*	5-10% / common

The remainder of Rice's Barn field is not wetland, so the desired vegetation described for the wetland edge would not be appropriate for the rest of the field. Upland shrublands do not occur naturally on the mesic loamy soil conditions here. If an upland shrub thicket is desired on this field, planting an assortment of native mesic shrubs and aggressive management of invasives would be possible, but there is no NVC association that can inform what the desired vegetation should be. *Cornus amomum, Viburnum dentatum, Clethra alnifolia, Aronia melanocarpa,* as well as *Prunus serotina* may be planted, and once established, may shade out exotic invasive species in the understory.

---

[41] Species composition drawn from NVC description of CEGL006406, element occurrence descriptions from the New York Natural Heritage Program, description of Dogwood – Arrowwood Successional Wet Shrubland, and field notes from Great Meadows NWR visits during NVC mapping.
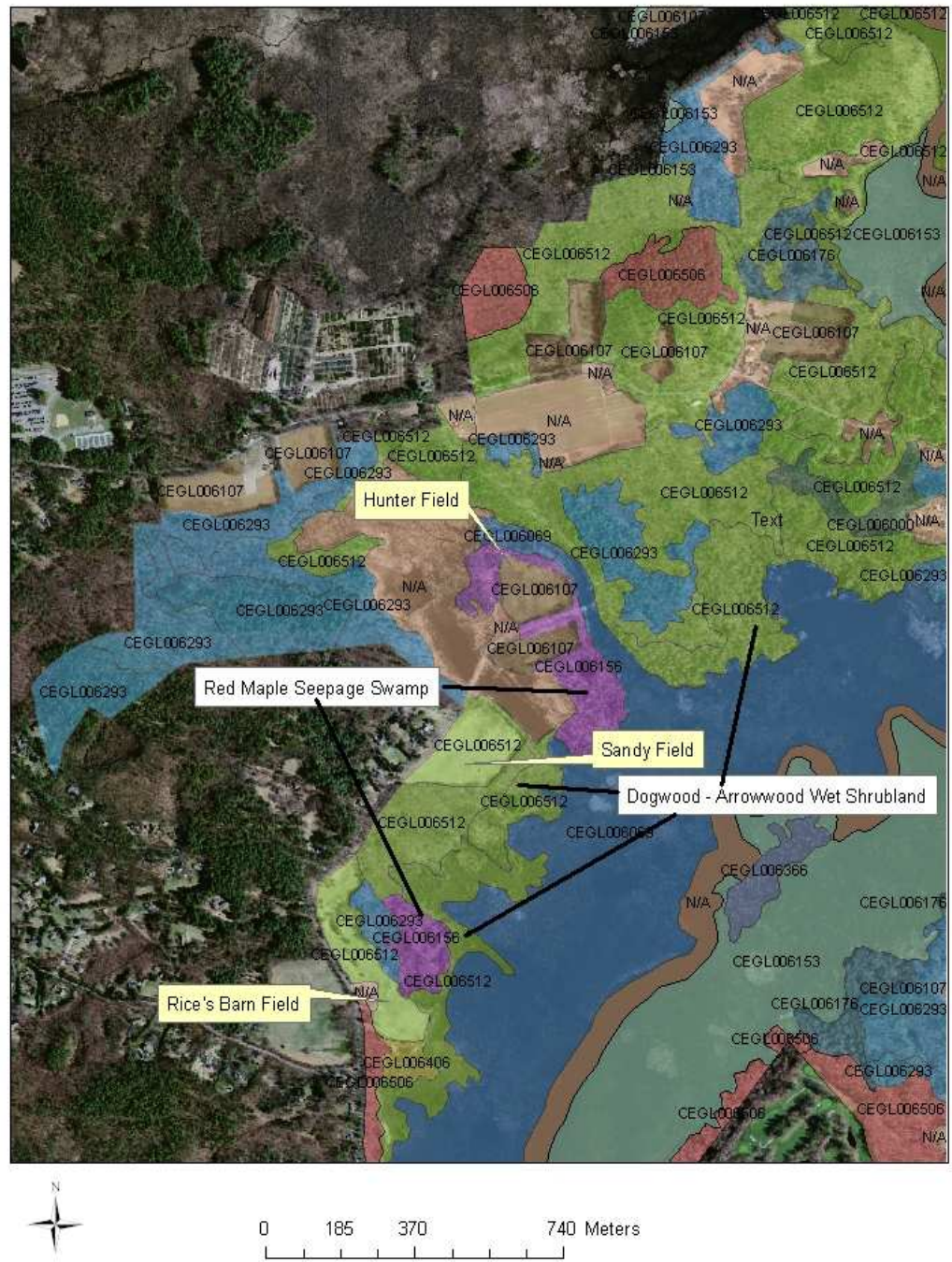
Figure 5 Assumed association names for wet shrubland and red maple swamp polygons incorrectly attributed on original NVC map

Target Vegetation at Sandy Field

Much of Sandy field is similar in composition to the upland field at Rice's Barn field, and, if desired, could be managed the same way by planting an assortment of native shrubs and aggressively removing exotics until they are shaded out by the dense native shrub overstory. A small portion of Sandy field supports a well-drained sandy area dominated by two native grasses, *Schizachyrium scoparium* (little bluestem) and *Eragrostis spectabilis* (purple lovegrass), suggesting some similarity to "sandplain grassland", a vegetation type that at sizes of 200 ha or more provides good habitat for grassland birds in the northeast (Weik 1998). However, the small size of this patch precludes its suitability for grassland birds, and its location as a small island within a larger wetland complex does not provide potential for expansion. Introduction of sandplain shrubs such as *Vaccinium angustifolium* (lowbush blueberry) and *Gaylussacia baccata* will not produce high-quality migratory bird habitat, because the low stature of the shrubs does not provide adequate perches. However, introduction of sandplain shrubs and periodic removal of tree seedlings will likely further the goal of decreasing invasive exotic species. A similar "sandplain grassland" occurs on a powerline right-of-way at Minuteman National Historical Park (Gawler et al. 2005), a short distance from Great Meadows. Although not of natural origin, it is characterized by the same vegetation structure and composition as that of natural sandplain grasslands.[42] In the event that management for this type is desired at Sandy Field, the following description, based on that of the occurrence at Minute Man National Historical Park, may be used to guide management:

Target Average Species Composition

Stratum	Lifeform	Species	Cover Range / Frequency
Short shrub/sapling	Broad-leaved deciduous shrub	*Vaccinium angustifolium*	20-80% / common
Short shrub/sapling	Broad-leaved deciduous shrub	*Vaccinium pallidum*	10-50% / common
Short shrub/sapling	Broad-leaved evergreen shrub	*Arctostaphylos uva-ursi*	10-50% / common
Short shrub/sapling	Broad-leaved evergreen shrub	*Comptonia peregrina*	10-50% / common
Herb (field)	Forb	*Baptisia tinctoria*	10-50% / common
Herb (field)	Forb	*Sericocarpus asteroides*	2-5% / common
Herb (field)	Forb	*Solidago juncea*	2-5% / common
Herb (field)	Forb	*Solidago odora*	2-5% / occasional
Herb (field)	Forb	*Solidago puberula*	2-5% / occasional
Herb (field)	Forb	*Lechea intermedia*	1-2% / common
Herb (field)	Forb	*Linaria canadensis*	<1-1% / common
Herb (field)	Forb	*Viola fimbriatula*	1-2% / occasional
Herb (field)	Forb	*Lysimachia quadrifolia*	2-5% / common
Herb (field)	Forb	*Symphyotrichum dumosum*	5-10% / common
Herb (field)	Graminoid	*Carex pensylvanica*	10-50% / common
Herb (field)	Graminoid	*Danthonia spicata*	10-50% / common
Herb (field)	Graminoid	*Schizachyrium scoparium*	10-50% / common
Herb (field)	Fern or fern ally	*Pteridium aquilinum*	10-50% / common

---

[42] The "naturalness" of sandplain grasslands has been a subject of debate to ecologists in New England for some time. While sandplain grasslands were not likely to have occurred at a large scale in presettlement times, the existence of grassland species such as the heath hen in New England suggest that this was a naturally occurring type, probably occurring as open patches maintained by periodic fires in the forested landscape, and in maritime settings kept open by wind and salt spray (Vickery et al. 1994).

Target Vegetation: Rachel Carson

To support the primary goal of increasing high-quality habitat for the known populations of New England cottontail, and the secondary goals of decreasing invasive species cover and providing habitat for migratory songbirds on the refuge, the existing old fields will be managed to increase native shrub cover and decrease the incidence of invasive species.

Desirable New England cottontail habitat is comprised of high stem densities. Litvaitis et al.(2006) considered habitat patches with stem densities of 9,000 stems per ha or higher to be suitable candidates in their search for patches potentially occupied by New England cottontail. Litvaitis and Jakubus (2004) suggest significantly greater densities, >50,000 stem units per hectare as optimal habitat. Chapman et al. (1982) note that in Connecticut, New England cottontails preferred brush piles for hiding and resting, and where brush piles were absent, they used herbaceous and shrub cover. Habitat diversity in the form of varied vegetation structure, including shrubby fields and briar patches was also noted to be desirable. In general, large patches of monotypic structure were regarded to be less suitable. In addition to cover, habitat must also provide food. Chapman (1974) noted that in New England cottontails studied, over half of stomach contents were grasses and clovers, with herbs, shrubs, twigs, buds, fruit pulp, and seeds comprising the remainder. It was also noted that *Juncus effusus*, a common rush in marshes, was also a preferred food. Gill and Healey (1974) noted that cottontails (New England cottontails not specified) browsed *Smilax rotundifolia, Gaylussacia baccata, Spiraea tomentosa, Comptonia peregrina* (sweetfern)*, Rhus typhina,* and *Ilex verticillata,* and ate the fruits of *Viburnum dentatum* and *Ilex verticillata.* Other common browse species noted by Litvaitis et al. (2006) include *Rubus* spp., *Populus tremuloides* (trembling aspen)*,* and *Acer rubrum.* Chapman and Feldhamer (1982) noted that grasses comprise a substantial portion of the diet of cottontails, but also noted that importance of leafy succulent forbs may be underappreciated as a potential source of amino acids and trace minerals.

There is no natural analog to a self-perpetuating upland shrubland in the northeast, where succession generally leads to forest except in the most exposed maritime or alpine settings. No existing NVC association can be drawn on to form the basis for the desired community here. However, shrubland forest openings may be simulated by removing invasive shrubs as planned, and allowing native shrubs to grow and spread, supplemented by plantings. I recommend that thicket-forming species such as *Rubus* spp., *Smilax rotundifolia,* and *Toxicodendron radicans* in particular be encouraged. At forest edges, low-growing shrubs such as *Vaccinium angustifolium* and *Gaylussacia baccata* are desirable. The existing *Rhus typhina* is a taller shrub with an open understory, its habit more of a small tree in that respect, and may not be as beneficial in providing adequate cover, although this species does provide a good winter food source. *Viburnum dentatum* is a low-growing shrub that would be suitable, but infestation of Viburnum leaf beetle has impacted populations of this species on the refuge and would require additional management.

Wetland shrub thickets occupying small patches are also not well defined in the NVC, particularly since they are so variable and result from a number of different land use and disturbance scenarios. Therefore, the suggested composition of wetland shrub thickets

occupying low wet areas in the existing fields is based on wetland species noted to occur in the refuge, as well as known food preferences of New England cottontails.

Target Environmental Condition: Invasive species absent or negligible

Target Dynamics: Self-perpetuating shrubland comprised of native species in the current old fields and in forest openings.

Target Vegetation Structure and Composition: Dense low shrubland thickets with high stem densities comprised of native shrubs, interspersed with herbaceous patches already occurring on existing old fields. Forest openings with closely situated dense low shrubs and vines within the 160 acre target patch size. Small wetland areas occupied by native shrubs, grasses, sedges, and forbs.

Target Patch Size: 160 acres, including the 18 acres of existing old fields, will accommodate a breeding season range of 500m from home range.

Below is described the target species composition of three sub-habitats at the Cutts sites; the upland shrub thicket; wetland shrub thicket for low wet areas, and forest edges and proposed forest openings:

Target Average Species Composition – upland shrub thicket[43]

Stratum	Lifeform	Species
Tall shrub / sapling	Broad-leaved deciduous shrub	*Photinia melanocarpa*
Tall shrub / sapling	Broad-leaved deciduous tree	*Acer rubrum*
Tall shrub / sapling	Broad-leaved deciduous tree	*Populus tremuloides*
Short shrub	Broad-leaved deciduous shrub	*Ilex verticillata*
Short shrub	Broad-leaved deciduous shrub	*Viburnum dentatum*
Short shrub	Broad-leaved deciduous shrub	*Rosa carolina*
Short shrub	Needle-leaved evergreen shrub	*Juniperus communis*
Herb / Field	Vine / Liana	*Rubus allegheniensis*
Herb / Field	Vine / Liana	*Rubus flagellaris*
Herb / Field	Vine / Liana	*Vitis riparia*
Herb / Field	Vine / Liana	*Smilax rotundifolia*
Herb / Field	Vine / Liana	*Toxicodendron radicans*
Herb / Field	Vine / Liana	*Amphicarpaea bracteata*
Herb / Field	Graminoid	*Deschampsia flexuosa*
Herb / Field	Graminoid	*Carex swanii*
Herb / Field	Forb	*Solidago canadensis*

---

[43] Because there is no description of this type in the NVC, no target percent cover is attempted here, nor is more than a preliminary definition of an herbaceous layer. Species are drawn from lists taken on Cutts Island by Clotilde Straus, and supplemented with native forbs and graminoids known to be preferred food.

Target Average Species Composition – wetland shrub thicket

Stratum	Lifeform	Species
Tall shrub / sapling	Broad-leaved deciduous shrub	*Vaccinium corymbosum*
Short shrub	Broad-leaved deciduous shrub	*Ilex verticillata*
Short shrub	Broad-leaved deciduous shrub	*Spiraea latifolia*
Short shrub	Broad-leaved deciduous shrub	*Spiraea alba*
Herb / Field	Vine / Liana	*Rubus allegheniensis*
Herb / Field	Vine / Liana	*Rubus flagellaris*
Herb / Field	Graminoid	*Juncus effusus*
Herb / Field	Graminoid	*Calamagrostis canadensis*
Herb / Field	Graminoid	*Carex scoparia*
Herb / Field	Graminoid	*Glyceria canadensis*

Target Average Species Composition – forest edge and forest openings

Stratum	Lifeform	Species
Tall shrub / sapling	Broad-leaved deciduous shrub	*Lyonia ligustrina*
Short shrub	Needle-leaved evergreen shrub	*Juniperus communis*
Short shrub	Broad-leaved deciduous shrub	*Comptonia peregrina*
Short shrub	Broad-leaved deciduous shrub	*Vaccinium angustifolium*
Short shrub	Broad-leaved deciduous shrub	*Gaylussacia baccata*
Short shrub	Broad-leaved deciduous shrub	*Aralia hispida*
Herb / Field	Vine / Liana	*Rubus allegheniensis*
Herb / Field	Vine / Liana	*Rubus flagellaris*
Herb / Field	Vine / Liana	*Smilax rotundifolia*
Herb / Field	Vine / Liana	*Parthenocissus quinquefolia*
Herb / Field	Graminoid	*Deschampsia flexuosa*
Herb / Field	Fern or fern ally	*Dennstaedtia punctilobula*
Herb / Field	Forb	*Aralia nudicaulis*

Discussion – Rachel Carson NWR shrublands

According to Chapman (1975), the typical autumn home range for New England cottontails is 0.5 – 1.8 acres, with ranges increasing during the beginning of breeding season. Mark and recapture studies indicated that rabbits were found up to 530 from their December ranges. Litvaitis and Jakubas (2004) noted that New England cottontails are found to live at densities greater than carrying capacity when habitat and travel corridors are limited. Densities were found to be less in larger patches, approximately one individual per acre. Tefft (2006) noted that at least 25 acres is required to support a viable population of NE cottontails, and Litvaitis et al. (2006) suggested 10 – 25 ha (25 – 61 acres) as core habitat.

Because the proposed management area is small at 18 acres, consideration may be given to creating several shrub-dominated openings within the surrounding forest, providing an area of over 160 acres of contiguous habitat. These openings should be in close proximity; Litvaitis and Jakubas (2004) indicated that New England cottontails are reluctant to venture more than 5m from cover. Canopy openings may also be created in close proximity to the several small shrub-dominated wetlands occurring in this forest patch. At Rachel Carson NWR, the forest patch surrounding the study area is classified as White Pine – Oak Forest (*Pinus strobus - Quercus (rubra, velutina) - Fagus grandifolia* Forest) in the NVC. It is a common type comprising much of central and northern New England, and the 160-acre patch proposed for management is a negligible portion of the total area

occupied by this type over the entire range. In fact, it is likely that coastal regions supporting this association experienced relatively frequent small canopy openings as a result of storms and blow-downs, and that increasing structural diversity will increase ecological integrity. Creation of shrub-dominated openings will also increase habitat for migratory songbirds dependent on early successional habitats, such as prairie warblers and golden-winged warblers (Litvaitis 2003).

The composition of this forest patch is largely dominated by white pine, which generally supports a sparse to non-existent shrub layer due to heavy shade. Removal of pines and establishment of deciduous trees and low shrubs as noted above would increase the structural diversity of this forest patch. In addition, Chapman (1975) suggested that a very effective temporary management technique for New England cottontail is the establishment of brush piles. Such habitat was noted by Dalke (1942) to provide high quality winter cover as well as food sources.

Conclusion

The adaptive management program adopted by the USFWS and being implemented by biologists of the four refuges in this report is a pragmatic and effective means to attaining several goals at once: removal and containment of exotic species, restoration of natural vegetation, and establishment or improving habitat for migratory birds and the New England cottontail. The information provided in this paper is intended to guide management actions of biologists in a way that best mimics natural conditions, or if there is no natural analog, to manage for native species.

I recommend an additional reference (Gill and Healey 1974) that provides detailed information on soil conditions, as well as planting and propagation methods for a variety of shrubs mentioned in this report.

References

Baird, J.W. 1980. The selection and use of fruit by birds in an eastern forest. Wilson Bulletin 92: 63-73.

J.A. Chapman. 1975. *Sylvilagus transitionalis.* Mammalian Species 55: 1-4. The American Society of Mammalogists.

J.A. Chapman and G.A. Feldhamer (eds.) 1982. Wild mammals of North America. John Hopkins University Press, Baltimore, MD.

Dalke, P.D. and P.R. Sime. 1942. Food habits of eastern and New England cottontails. Journal of Wildlife Management 5: 216-228.

Faber-Langendoen, D. G. Kittel, K. Schulz, E. Muldavin, M. Reid, C. Nordman, Pat Comer. 2008. Assessing the Condition of Lands Managed by the U.S. Army Corps of Engineers: Level 1 Ecological Integrity Assessment. NatureServe, Arlington, VA.

Faber-Langendoen, D. G. Kittel, K. Schulz, E. Muldavin, M. Reid, C. Nordman, Pat Comer. 2009. Assessing the Condition of Ecosystems to Guide Conservation and Management: NatureServe's Level 1 Ecological Integrity Assessment Method. NatureServe, Arlington, VA. + Appendices

Gawler, S.C., R.E. Zaremba, and B.Aguis. 2005. Draft final report: vegetation mapping of Minuteman National Historical Park. NatureServe report to the National Park Service. NatureServe, Boston, MA. 132 pp. + appendices.

Gill, J.D. and W.M. Healey (eds). 1974. Shrubs and Vines for Northeastern Wildlife. USDA Technical Report No. 9 Northeastern Forest Experiment Station, Darby, PA.

Hauer, F.R., B.J. Cook, M.C. Gilbert, E.J. Clairain Jr., and R.D. Smith. 2002. A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains. U.S. Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS. ERDC/EL TR-02-21.

Litvaitis, J.A. 2001. Importance of early successional habitats to mammals in eastern forests. Wildlife Society Bulletin 29: 466-473.

Litvaitis, J.A. 2003. Shrublands and early successional forests: critical habitats dependent on disturbance in the northeastern United States. Forest and Ecology Management 185: 1-4.

Litvaitis, J.A. and W. J. Jakubas. 2004. New England cottontail (*Sylvilagus transitionalis*) assessment. 73 pp.

Litvaitis, J.A., J.P. Tash, M.K. Litvaitis, M.N. Marchand, A.I. Kovach, and R. Innes. 2006. A range-wide survey to determine the current distribution of New England cottontails. Wildlife Society Bulletin 34: 1190-1197.

McDonnell, M.J. 1979. The flora of Plum Island, Essex County, Massachusetts. Station Bulletin 513. New Hampshire Agricultural Experiment Station. University of New Hampshire, Durham, NH. 110 pp.

NatureServe. 2009. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA. U.S.A. Data current as of 19 February 2008.

Neiring, W.A. and F.E. Egler. 1955. A shrub community of *Viburnum lentago,* stable for twenty-five years. Ecology 36: 356-360.

O'Brien, K., N. Pau, S. Payton. 2008. Proposed management prescriptions and site condition summary for shrub adaptive management consultancy. Unpublished paper for USFWS.

Parrish, J.D. 1997. Patterns of frugivory and energetic condition in nearctic landbirds during autumn migration. Condor 99: 681-697.

Smith, S.B., K.H. McPherson, J.M. Backer, B.J. Pierce, D.W. Podlesak, and S.R. McWilliams. 2007. Fruit quality and consumption by songbirds during autumn migration. The Wilson Journal of Ornithology 119:419-428.

Suthers, H.B., J.M. Bickal, and P.G. Rodewald. 2000. Wilson Bulletin 112:249-260.

Tefft, B.C. 2006. Managing shrublands and old fields. pp.28-34 in Oehler, J.D., D.F. Covell, S. Capel, and B. Long (eds.). Managing grasslands, shrublands, and young forests for wildlife: a guide for the northeast. The Northeast Upland Habitat Technical Committee, Massachusetts Division of Fisheries and Wildlife. 139 pp. + appendices.

Vickery, P.D., M.L. Hunter, and S.M. Melvin. 1994. Conservation Biology 8: 1087-1097.

US EPA. 2001. National Land Cover Data (NLCD 2001). http://www.epa.gov/mrlc/nlcd-2001.html

Weik, A. 1998. Conservation of grassland birds in Maine: field survey of breeding birds, 1997-1998. Maine Department of Inland Fisheries and Wildlife Miscellaneous Report, Bangor, Maine.